# A COMPARATIVE EVALUATION OF THE FRACTURE RESISTANCE OF FIVE DIFFERENT DOWEL SYSTEMS IN ENDODONTICALLY TREATED MANDIBULAR FIRST PREMOLARS-AN IN VITRO STUDY

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*In the partial fulfillment of the degree of*

## MASTER OF DENTAL SURGERY

## Branch I

## Prosthodontics and Crown & Bridge

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# CERTIFICATE

This is to certify that this dissertation titled "**A comparative evaluation of the fracture resistance of five different dowel systems in endodontically treated mandibular first premolars-An in vitro study**" is a bonafide record of work done by **APARNA MOHAN** under our guidance during her postgraduate study during the period ***2009-2012*** under **THE TAMIL NADU DR MGR MEDICAL UNIVERSITY, CHENNAI** in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY IN PROSTHODONTICS & CROWN BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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# DECLARATION

I hereby declare that this dissertation entitled **"A comparative evaluation of the fracture resistance of five different dowel systems in endodontically treated mandibular premolars-An in vitro study"** is a bonafide record of work undertaken by me and that this thesis or a part of it has not been presented earlier for the award of any degree, diploma, fellowship or similar title of recognition.

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# CONTENTS

# LIST OF ABBREVIATIONS

| | |
|---|---|
| CMP | Cast Metal Post |
| FRC | Fiber Reinforced Composite |
| CFP | Carbon Fiber Post |
| SS | Stainless Steel |
| ZRC | Zirconium Ceramic |
| µm | Micro meter |
| ANOVA | Analysis of Variance |
| EDTA | Ethylene di-amine tetra acetic acid |
| FEA | Finite Element Analysis |
| FEM | Finite Element Method |
| SEM | Scanning Electron Microscopy |
| KN | Kilo Newton |

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# A COMPARATIVE EVALUATION OF THE FRACTURE RESISTANCE OF FIVE DIFFERENT DOWEL SYSTEMS IN ENDODONTICALLY TREATED MANDIBULAR PREMOLARS-AN IN VITRO STUDY

## ABSTRACT

**Introduction**

An extensive tooth structure loss significantly weakens the remaining tooth, making dowel, core and crown necessary. The chief function of a dowel is to strengthen the tooth and to improve the retention of extra coronal restorations of non-vital teeth. Loss of retention is the most frequent cause of dowel failure. The interaction of many factors, such as the design of the tooth preparation, fit of the casting, dowel diameter and the design, dowel length, luting medium, cementation procedure, surface characteristics and location in the dental arch appears to influence the potential for dislodgement. Dowels with greater retention are more resistant to dislodgement due to occlusal stresses.

**Aims & Objectives:**

To determine the fracture resistance and mode of failure of five different types of dowel systems

## Methodology

Fifty freshly extracted intact human mandibular premolars decoronated at a level of 2mm from the Cemento-enamel junction were endodontically treated. Five groups of ten specimens were formed (N=50).Specimens were immersed in distilled water and maintained at $37^{0}$C for 72 hrs. Root canal post space preparation was initiated using gates glidden drill to remove 8mm of filling material. Each specimen was restored with posts of five different types. This included Cobalt Chromium cast metal post (group 1), Glass Fiber reinforced post (group 2) Carbon post (group 3) Stainless Steel post (group 4) and Zirconium post (group 5) of 1.3mm diameter. The test specimens were cemented using Composite resin luting cement and control groups were cemented using Zinc phosphate cement. The roots were further embedded in cylindrical acrylic resin blocks of 3cm x 2cm size. The specimens were loaded in a universal testing machine (Model 3345 Instron Corp) and a compressive load was applied at 90 degree to the occlusal surface until fracture, at a cross head speed of 1mm/min.

## Results

Fracture resistance of specimens of each group was determined using Universal testing machine by applying a static compression load and the maximum load at break was recorded. The value of maximum load at failure ranged between 4.19 KN and 5.32KN for the samples of Group1 during the compression test. The value of maximum load at failure of Group 2 was between 1.83 KN and 2.42KN, for

Group 3 ranged between 1.41 KN and 2.19KN, for Group 4 ranged between 1.14 KN and 1.86 KN and for Group 5 ranged between 1.96 KN and 2.60 KN.

**Summary**

The present study was done to evaluate the fracture resistance of five different post systems which were commonly used for restoring endodontically treated teeth with major loss of coronal tooth structure. The study concluded teeth restored with cast metal posts and cores exhibited the highest fracture resistance when compared with the other prefabricated post used in the present study. The teeth restored with Zirconia posts showed catastrophic vertical root fracture.

**Clinical Implications**

From the data obtained from the present study fiber reinforced composite post and carbon fiber posts can be suggested as best options of reinforcing endodontically treated teeth with loss of coronal tooth structure. As the zirconia posts showed vertical root fracture they should be avoided in case of patients with para-functional habits.

# *Introduction*

Restorative methods for pulpless teeth using various post and core systems have been widely investigated with the aim of achieving long term promising prognosis. The longevity of endodontically involved teeth has been greatly enhanced by continuing developments made in the endodontic therapy and the restorative procedures. The problem of restoring such teeth is associated with decrease in the blood flow and loss of tooth structure.

The success of the endodontic therapy depends upon a combination of three dimensional fluid tight obturation and an adequate post endodontic restoration. This treatment procedure makes the pulpless teeth to function as an integral part of the dental arch. Usually an endodontically treated tooth should be restored using a crown. A post is indicated in the endodontically treated teeth when it is severely damaged. Coronal reinforcement is also indicated in teeth were more occlusal loads are directed.

The restoration to be used on endodontically treated teeth is dictated by the extent of the coronal destruction and by the type of teeth. If a moderate sized tooth is intact except for the endodontic access, a good access cavity restoration is sufficient. This can be done either with reinforced Glass Ionomer base or composite restoration. Placement of a dowel in such a tooth is more likely to weaken the tooth rather than strengthen it. However a non-vital tooth with excessive destruction of dentin bears insufficient sound dentin to support a crown, which provides retention otherwise gained from the coronal tooth structure.

Post and core systems have been used to restore endodontically treated teeth for more than 250 years. As early as 1728, Pierre Fauchard used Tenons, which were metal posts screwed into the roots of the teeth to retain bridges. In the late 19$^{th}$ century Richmond crown was introduced. During 1930s the custom cast post and core was developed to replace the one-piece post crowns. Prefabricated posts and resin restorative materials to fabricate post and core systems were introduced in the 1960s. Subsequently prefabricated post and core systems are available in a variety of materials. Traditionally, cast post and cores were made of metal and its alloys. Currently the material of choice is stainless steel, titanium, and titanium alloys. Other metal alloys that have been used are platinum-gold-palladium, chromium containing alloys, and brass. Newer materials like Zirconia and fiber reinforced posts are widely used for restoration of teeth

Post is a relatively rigid material placed in the root of the non-vital tooth which extends coronally to anchor the material which supports the crown. Endodontic posts should be used only when there is insufficient tooth structure remaining to support the final restoration. Thus a post should be both retentive as well as protective in function by dissipating forces along the long axis of the tooth.

The ideal properties reflect the underlying physical nature of the dowel. Each dowel system has unique combination of composition, shape, size and surface configuration. In addition, cements, dowel space preparation techniques, additional restorative anti-rotational features and internal adaptation of the walls directly affect the success of the restoration.

The posts may be classified into Custom cast posts and pre-fabricated posts. Prefabricated posts are divided according to shape, retention and the material used. The posts may be classified based on their shape and configuration (geometry), and whether it is passive or active (nature). Materials usually available for posts fabrication are metals, composite material reinforced with carbon, silica and polyethylene fibers or ceramic.

Endodontic posts provide retention for the core material and distribute the masticatory stresses along the long axis of the tooth thus preventing tooth fracture. If teeth are not restored properly it can lead to the fracture and failure of the restoration in endodontically treated teeth. The fracture resistance of such tooth is influenced by the loss of tooth structure as well as its position in the arch. Due to extirpation of the pulp, the mechanoreceptors are lost which in turn lead to fracture of teeth. These results in pressure which are two folds in endodontically treated teeth than on a normal vital tooth. Various studies have reported that a number of endodontically treated teeth are restored to their original function with the use of intra-radicular devices.

Prosthetic restoration of root filled tooth frequently requires pre-prosthetic treatment of the remaining tooth structure prior to fitting the permanent restoration. Despite the various attempts that have been made, vertical root fractures are still encountered in everyday clinical practice. Although it is acknowledged that minimal tooth reduction in endodontic and restorative procedures are the most effective measures for preventing fracture of the teeth, it is often necessary to restore the teeth appropriately. In such cases, the best restorative methods for effectively reinforcing pulpless teeth need to be identified.

In case of insufficient coronal tooth structure, the root canal space may be utilized for the retention of the core. Clinical longevity of such dowel-and-core restoration can be influenced by many factors such as, the magnitude and direction of the occlusal load, design of the dowel, thickness of the remaining dentin, and quality of the cement layer. Despite of the steady evolution in the range of post and core materials, and the techniques, failure of post retained crowns are recorded in various studies.

The fracture resistance of dowel-restored teeth has been the subject of numerous studies in the past. Many factors governed the clinical performance of post and core restorations which may be mechanical in the form of post dislodgement, post and crown fractures ,Para-functional or cyclic loading factors and thermal or chemical influences.

Materials with which the posts are fabricated presents with certain properties that make them unsuitable for reinforcing the tooth. Hence it is necessary to evaluate the various parameters of post systems, making it applicable for clinical purpose. The purpose of the present study was to compare the fracture resistance and mode of failure of endodontically treated mandibular premolars restored with five different endodontic dowel systems which included custom made cast post (Cobalt-Chromium), Stainless steel post, Carbon fiber post, Glass fiber post and Zirconium post.

# *Aims & Objectives*

## AIM

To determine the fracture resistance of five different types of dowel systems in comparison to the cast metal post.

## OBJECTIVES:

1. To evaluate the fracture resistance of cobalt chromium cast metal post.
2. To evaluate the fracture resistance of fiber reinforced post.
3. To evaluate the fracture resistance of carbon fiber post.
4. To evaluate the fracture resistance of stainless steel post.
5. To evaluate the fracture resistance of Zirconium post.

6. To compare the fracture resistance of different post systems used in the present study.

7. To determine the best post system among the study groups.

# *Review of Literature*

***Guzy, G.E. and Nicholls (1979)***[1] compared the breaking loads of endodontically treated teeth, with and without cemented posts. In this in vitro study the teeth were prepared for root canals and posts. Access preparations simulated those of teeth with large pulp chambers. Half of the teeth were merely restored with silicate cement. The other half had Kerr Endo-Posts (size 100) cemented with zinc phosphate cement. The teeth were stressed to failure on an Instron testing machine, with forces applied at 130 degrees to the long axis of the tooth. The study concluded that there were no statistically significant results.

***Chan, R., and Bryant, R. (1982)***[2] compared the resistance to fracture and the failure characteristics of endodontically treated posterior teeth. Freshly extracted, single-rooted, mandibular premolar teeth were mounted in acrylic with a silicone liner. Three types of post-cores were constructed and tested by Hounsfield Tensometer metal plunger. Post-cores tested were: 1. Cast type III gold, 2. Amalgam/steel post combination, and 3. Composite resin/steel post combination. Results showed that the Cast-gold specimens required less force before failure occurred. It was concluded that amalgam and composite resin cores with cemented metal posts as an acceptable alternative to the cast-gold post-core foundation for endodontically treated posterior teeth.

***John A. Sorensen*** and ***Michael J. Engelman(1990)***[3] determined the effect of different post designs and varying amount of post-to-canal adaptation on the fracture resistance of endodontically treated teeth. Cast post and cores, and crowns were waxed, casted, and luted with zinc phosphate cement on a static loading device. The teeth were embedded in acrylic resin and the crowns were loaded on a universal testing machine at 130 degrees to the long axis of the tooth until failure. Maximum adaptation of the residual root structure with a tapered post significantly increases the fracture resistance of endodontically treated teeth. Tapered posts resulted in fractures that were directed more apically and lingually. Parallel-sided posts had a lower frequency of fracture upon failure, involving less tooth structure. Parallel-sided posts surrounded by large amounts of cement had no significant effect on failure loads.

***Brett I. Cohen et al (1993)***[4] compared the cyclic fatigue of six prefabricated posts systems with an in vitro fatigue machine that simulated clinical fatigue conditions. The study concluded that the stresses generated by the fatigue testing apparatus was within the range similar to that of the average biting force of the natural dentition on static loading applied to the test sample.

***Marie-Charlotte (1995)***[5] evaluated the in vitro strength of post-and-cores and masticatory load to verify the longevity of post-and-core restorations. A biomechanical model was developed to predict the in vivo longevity which was applied to direct post-and-core restorations with amalgam or composite cores. Both experimental and laboratory strength values and theoretical clinical strength values were used in the model. The results showed clinical failure rate of about 1% per year for post-and-core restorations. And it was concluded that the mechanical properties of the post and-core restorations were adequate for clinically relevant loading conditions

***Charles J Goodacre (1995)***[6] reviewed guidelines for the optimal preparation of teeth to receive posts and cores. The review concluded that length ideally would be three fourths of the root length, post diameter not to exceed one third of the root diameter at any location, and post tip diameter should be 1 mm or less. Cervical bevel or ferrule increases the fracture resistance. Cervical tooth structure should be retained or the finish line should be extended cervically to engage 1 to 2 mm of tooth structure.

***Duret B., Duret, F. et al (1996)***[7] reviewed on the long-life physical property, preservation and post-endodontic rehabilitation With the Composipost. Studies using the Finite element method showed that the biomechanical disturbances caused by the inclusion of materials such as Nickel, Chrome, Zircon with a modulus of elasticity that is superior to that of dentine does not disturb the flow of stress inside the root. The C-Post, made of carbon epoxy resin, accommodated the demands of the dentin, as well as the in vitro stress linked to the prosthesis. The internal structure, consisting of long high-performance, unidirectional and equally stretched carbon fibers, conferred a totally original behavior that was adapted to clinical objectives. In addition, the C-Post had a fracture resistance superior to most metals.

***Daniel B. Mendonza (1997)***[8] evaluated the ability of resin bonded posts to reinforce teeth that are structurally weak in the cervical area against fracture. Parallel sided preformed posts were cemented to roots with canal flared at the cervical third to simulate weakened area. Three types of resin cements (Panavia, Z-100 and C& B Meta Bond) and Zinc phosphate cement were used and load was applied. The results showed that, when posts were cemented with resin cements, the fracture resistance of the roots was similar. The forces needed to fracture the roots in the Zinc phosphate group were lower than in the composite cement groups, but statistically different only from Panavia group.

***Giovanni E. Sidoli et al (1997)***[9] compared the in vitro performance of the failure characteristics of the Composipost system against the existing post and core combinations. Results demonstrated that specimens restored with Composipost system exhibited inferior strength properties compared to other post and core systems tested.

***Arturo Martinez-Insua et al (1998)***[10] compared the fracture resistances of pulpless teeth restored with a cast post and core or carbon-fiber post with a composite core. Significantly higher fracture thresholds were recorded for the cast post and core group. Results showed that teeth restored with cast posts typically showed fracture of the tooth, although at loads rarely occurring clinically.

***Sirimai, Riis*** and ***Morgano (1999)***[12] compared the resistance to vertical root fracture of extracted teeth treated with post-core systems that were modified with polyethylene woven fibers with those treated with conventional post and core systems. Polyethylene woven fiber and composite resin without a prefabricated post resulted in significantly fewer vertical root fractures, but mean failure load was the lowest. Smaller diameter prefabricated posts combined with polyethylene woven fiber and composite cores improved resistance to failure. Traditional cast posts and cores were the strongest of the 6 post and cores used in the study.

***Bruce Glazer (2000)***[13] evaluated the success of carbon fiber reinforced epoxy resin (CFRR) posts used to restore endodontically treated teeth. All the teeth in the study had lost more than 50% of their coronal structure and according to the study CFRR posts were among the most predictable systems. CFRR posts in the upper anterior teeth were associated with a higher success rate and longer life than those placed in premolars, especially lower premolars. This study contributed to the growing body of evidence that supports the use of CFRR posts in the restoration of endodontically treated teeth.

***Rosentritt M (2000)***[14] compared the fracture strength of tooth-colored ceramic and fiber-reinforced posts as well as titanium posts with clinically proven gold alloy posts as a control. Regarding fracture strength, the ceramic posts with composite cores were an alternative to commonly used gold posts and cores. Post and core restorations with tooth-colored, translucent material offer an improved aesthetic especially in anterior restorations. Because of the high fracture strength prefabricated ceramic posts in combination with composite cores should prove their clinical applicability.

***Scotti and Malferrari (2001)***[15] evaluated the prosthetic aspects of endodontically treated tooth restoration and it was concluded that the conventional cast post/core, even if passively cemented, does not have good results. The posts strengthened with quartz or carbon fibers were equivalent in mechanical properties. The data on their adhesion capacity stated that an extremely accurate canal preparation was required to completely remove the gutta percha and the endodontic filling cement remaining on the walls would reduce the total adhesion surface of the hybrid layer and the effectiveness of subsequent composite cement.

***Cormier et al(2001)***[16] compared the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration .The study concluded that the fiber posts were readily retrievable whereas the remaining post systems (Para Post metal, Cosmo Post ceramic, cast post) were not retrievable.

***Marco Ferrari (2001)***[17] evaluated the efficacy of different adhesive techniques on bonding to root canal walls by Scanning Electron Microscopic investigation. It was concluded that quality, uniformity and predictability of the bonding mechanism obtained with the adhesive system applied on samples with a micro-brush was superior to the other groups used in the study, and the clinical procedure performed was more reliable and predictable for daily practice.

***Hong – So yang et al (2001)***[18] investigated the influence of occlusal stresses on various dowel designs in a restored, endodontically treated tooth by using

2-dimensional finite element analysis. When vertical force was applied ,the magnitude of stress of various dowel designs were similar but when loaded horizontally , the short dowel produced the greatest dentinal stress concentration and the tapered dowel showed the greatest stress concentration within the cement layer. Their study concluded that load direction had a much greater effect than the dowel design on maximum stress and displacement.

***Frank Butz et al (2001)***[19] compared the survival rate and the fracture strength of endodontically treated maxillary incisors restored with different post and core systems after exposure to an artificial mouth. Prefabricated titanium posts with composite cores and zirconia posts with ceramic cores, cast post and cores yielded comparable survival rates and fracture strengths for the restoration of teeth with moderate coronal defects. Combination of zirconia posts with composite cores could not be recommended for clinical use.

***Mark S .Hagge (2002***[20]***)*** evaluated the effect of dowel space preparation and composite cement thickness on retention of a prefabricated dowel. Their study concluded that for optimal dowel retention in oversized canal spaces, the cement thickness needed should be considerably greater than what was historically considered ideal.

***Mark S Hagge et al (2002)***[21] investigated the effects of different types of cements on the retention strength of prefabricated endodontic dowels placed into root canals previously obturated with gutta percha and a zinc oxide eugenol sealer. Their study concluded that Paraposts cements luted with resin cements in unobturated canals exhibited significantly higher retention than all cement groups luted in obturated canals. Among the obturated groups, resin cement resulted in greater retention of Paraposts than zinc phosphate; Glass Ionomer cement produced intermediate retention value.

***Seung Mi Jeong et al (2002[22])*** investigated the fracture resistance of three types of Zirconia posts in all ceramic post and core restorations thereby improving the strength between post and core. The study concluded that adhesively luted all ceramic cores on zirconia posts offered a viable alternative to the conventional technique.

***Akkayan & Gulmez(2002)***[23]compared the effect of one titanium and three esthetic post systems on the fracture resistance and fracture patterns of crowned endodontically treated teeth. The study concluded that titanium demonstrated least resistance to fracture loads, and higher failure loads were recorded for quartz fiber posts. Catastrophic fractures were observed in titanium and zirconia groups. Fractures that would allow repeated repair were observed in teeth restored with quartz fiber and glass fiber posts.

***Stankiewicz and Wilson (2002)***[24] reviewed on the benefit of using a ferrule as a part of the core or artificial crown in reinforcing root filled teeth. The literature demonstrated that a ferrule effect occurred owing to the artificial crown bracing against the dentin, extending coronal to the crown margin but it should not be provided at the expense of the remaining tooth or root structure.

***Robbins (2002)***[25] provided a rationale for the restoration of the endodontically treated teeth. Treatment recommendations were made in the areas of post design, placement technique, cement, core material and definitive restorations based on the review of a clinical and laboratory data. The review also concluded that the most important factor that has to be considered was the amount of remaining coronal tooth structure before final restoration rather than the post material and the cement and the core material

***Heydecke G and Peters M C (2002)***[26]conducted a study to compare the clinical and in vitro performance of cast posts and cores to that of direct cores with prefabricated posts in single-rooted teeth. A comparison of fracture loads in the in vitro studies revealed no significant difference between cast and direct posts and cores. The survival for cast posts and cores in two studies ranged from 87.2% to 88.1% and in a third study reached 86.4% for direct cores after 72 months.

***Aquaviva S. Fernandes et al (2003)***[27] reviewed on the factors determining the post selection. Most endodontically treated teeth required a post-and-core build-up for restoring the teeth to optimum health and function. Selection of a post and core system should satisfy many interrelated biologic, mechanical, and esthetic factors to optimally restore the endodontically treated tooth to adequate form and function.

***Albuquerque R C et al (2003)***[28] evaluated the effect of different anatomic shapes and materials of posts in the stress distribution on endodontically treated incisor. This study compared three post shapes made of three different materials. The study concluded that stress concentrations did not significantly affect the region adjacent to the alveolar bone crest at the palatine portion of the tooth, regardless of the post shape or material. However, stress concentrations on the post/dentin interface on the palatine side of the tooth root presented significant variations for different post shapes and materials. Post shapes had relatively small impact on the stress concentrations while post materials introduced higher variations on them.

***Oliviera et al (2003)***[29] performed a study on the distribution of mechanical stresses in the radicular dentin restored with different post systems, by means of Photoelastic and Finite Element techniques. The zirconium, stainless steel, titanium and cast metal posts presented mechanical properties which were different from those of the tooth structure, resulting in significant alterations over the mechanical behavior of the dental structure. The nonmetallic posts complied more satisfactorily with the requirements necessary to provide a mechanical behavior more similar with that of the dental structure, the compatibility among the mechanical properties found in these systems and the dentin providing a biometric behavior, reducing the risk of failure or fracture of the root.

***Marcela P. Newman et al (2003)***[30] compared the effect of three fiber reinforced composite post systems on the fracture resistance and the mode of failure of endodontically treated teeth. Results of the study showed that the load failure of the stainless steel posts were significantly stronger than all the composite posts used. But the mode of failure or the deflection of the fiber reinforced composite posts was protective to the remaining tooth structure.

***Borcic J. et al (2004)***[31] analyzed the mechanical behavior of a new polymeric composite post reinforced with glass fibers. The 3D finite element method (FEM) was selected to perform the stress analysis. The greatest stresses were observed in the palatal cervical region and in the intra-radicular parts of the post .The glass fiber composite post induce a stress field similar to that of the natural tooth, except in the cervical region, where the tooth has higher compressive stresses.

***Richard S. Schwartz and James W. Robbins (2004)***[33] reviewed the major pertinent literature on this topic, with an emphasis on major decision-making elements in post placement and restoration of endodontically treated teeth. Recommendations were made for treatment planning, materials, and clinical practices from restorative and endodontic perspectives.

***Sahafi et al (2004***[34]***)*** evaluated the effect of cement, post material, surface treatment, and shape on the retention of posts luted in the root canals of extracted human teeth and on the failure morphology. Failure morphology was analyzed stereo-microscopically. It was concluded that the retention and failure morphology of prefabricated posts were influenced by the type of cement and the material, shape, and the surface treatment of the post.

***Oblak et al (2004)***[35] compared the fracture resistance of prefabricated Zirconia posts of two diameters with a new retentive post head after different surface treatments. The results suggested that grinding leads to a significant drop in load to fracture of zirconia posts whereas airborne particle abrasion increased the fracture load.

***Vytaute Peciuliene and Jurate Rimkuviene (2004)***[36] confirmed the results of studies where it was stated that vertical root fractures are caused by poorly designed dowels (too short, too wide or both), inappropriate selection of the tooth as a bridge abutment or as a consequence of overzealous endodontic forces by a restoration that exerted lateral pressure on the axial walls of the preparation. Vertical root fractures can be detected early by listening to the patient’s chief complaints, carefully examining peri-apical and bitewing radiographs and performing a thorough clinical examination.

***Steven M Morgano and Carlos Sabrosa (2004)***[37] reviewed on the restoration of endodontically treated teeth. A pulpless tooth which has lost most of its coronal structure needed a restoration that conserves and protects the remaining tooth structure. Although the posts weakened the tooth, a post is indicated when there is inadequate remaining coronal tooth structure to retain a core material for an artificial crown, especially in case of an anterior tooth.

***Erik Asmussen et al (2005)***[38] conducted finite element analysis of stresses in endodontically treated, dowel-restored teeth. The variables studied were material, shape, bonding, modulus of elasticity, diameter, and length of the dowel. The dowels were made of glass fiber, titanium, or zirconia. The generated stresses decreased with respect to the dowel material in the following order: glass fiber, titanium, and zirconia. Stresses were in general higher with tapered than with parallel-sided dowels. Stresses were reduced by bonding and with an increasing modulus of elasticity, increasing diameter, and increasing length of the dowel. From the perspective of resistance to tooth fracture, a bonded, parallel-sided dowel of high elastic modulus is preferred.

***Simone Grandini et al (2005)***[40] evaluated the use of fiber posts and direct resin restorations for root treated teeth. They concluded that in the short term this treatment modality conserved the remaining tooth structure and resulted in good patient compliance

***Alessandro Lanza et al (2005)***[41] did a comparative study on the stress distribution in the dentine and cement layer of an endodontically treated maxillary incisor using Finite Element Analysis (FEA). The role of post and cement rigidity on reliability of endodontic restorations was discussed. They concluded that the influence of the cement layer elasticity in redistributing the stresses had been observed to be less relevant as the post flexibility is increased.

***Tan & Aquilino et al (2005)***[42] investigated the resistance to static loading of endodontically treated teeth with uniform and non-uniform ferrule configurations. The results showed that teeth restored with cast dowel and core with a 2mm uniform ferrule were more fracture resistant compared to those with non-uniform ferrule heights. Both 2mm ferrule and non-uniform ferrule groups were resistant than the group that lacked ferrule.

***Dermendgieva and K. Markova et al (2005)***[43] studied on the usage of different types of posts in incisors, premolars and molars of upper and lower jaw. The passive industrial posts are the most preferred and the most frequently used in the restoration of all groups of endodontically treated teeth. The study recommended that dentists had to evaluate the individual need of tooth restoration while looking for the balance between the biggest retention and the biggest resistance against fracture. Minimally damaged endodontically treated teeth without posts are more resistant against fracture compared to those restored with posts and filling material. The resistance against fracture is in a strong association with the thickness of the remaining dentin, especially in vertical-lingual direction

***Yalcin et al (2005)***[44]compared the fracture strengths of teeth restored with cast metal and ceramic dowel and cores supporting all ceramic crowns. From the study it was concluded that In-Ceram Spinell and IPS Empress 2 ceramic dowel and cores might be considered candidates for the endodontically treated teeth as the fracture strength of these restorations were above the maximum occlusal forces of natural dentition.

***Yoshihiro Goto et al (2005)***[45] compared the load fatigue resistance of endodontically treated teeth restored with three dowel and core systems. Fiber reinforced resin dowels and bonded composite cores under fatigue loading provided significantly stronger crown retention than the cast gold dowels and cores and the titanium dowels with composite.

***Mikako Hayashi et al (2006)***[46] designed to test the null hypothesis that there is no difference in the fracture resistance of pulpless teeth restored with different types of post-core systems and full coverage crowns. It was concluded that under the conditions of vertical and oblique loadings, the combination of a fiber post and composite resin core with a full cast crown is most protective of the remaining tooth structure.

***Ioli – IoannaArtopoulou (2006)***[47] compared the tensile retentive force of two composite core materials to two metallic and one non-metallic posts. Their study concluded that the metallic posts always provided higher tensile forces. The failure mode data showed that the adhesive failure rate was greater in the metallic groups than in the glass fiber post groups and the core diameter did not affect the retention value of the glass fiber posts.

***Nakamura T et al (2006)***[48] performed finite element analysis to evaluate the stress distribution in maxillary central incisors treated endodontically and restored with a post and an all-ceramic crown. Results showed that the fiber post produced less stress on the root dentin around the post tip than did the metal posts. The finding suggested that to reduce the stresses that cause root fracture, a long, thin fiber post should be used.

***Okada, D (2006)***[49] evaluated the influence of the prefabricated post on stress distributions in an abutment tooth restored with composite resin by 3-dimensional finite element analysis. The study showed that there were similar distributions of stress concentration at the apical area. However, in the dentin of the root around the end of the prefabricated posts, there were differences in stress concentration and the glass fiber posts showed lower stress values, which mean less possibility of root fracture.

***Dilmener et al (2006)***[50] determined and compared the fracture resistance of three recently introduced esthetic post and core systems with a cast metal post and core using a clinically related test method. The study concluded that the cast metal post/core and zirconia post/ceramic core foundations were found to be more fracture resistant than the zirconia/ post / composite core and the stainless steel post/ composite resin core foundations. The zirconia posts /ceramic core combinations demonstrated high resistance to fracture.

***Anil Kishen (2006)***[51] reviewed the mechanisms and risk factors for fracture predilection in endodontically treated teeth. The prognosis of root-filled teeth depends not only on the success of the endodontic treatment but also on the amount of remaining dentine tissue, and the nature of final restoration. Fractures of restored endodontically treated teeth are a common occurrence in clinical practice. Different mechanisms of fracture resistance in dentin and the biomechanical causes of fracture predilection in restored endodontically treated teeth were described. As per the various reviews dentinal, restorative, chemical, microbial, and age-induced factors are also causes that can lead to fracture in restored endodontically treated teeth to fracture are also reviewed.

***Pannna Narang (2006)***[52] compared the failure load and failure modes of two post and core systems using Fracture Strength Test. Finite Element Models were used for the comparison of pattern of stress distribution between the two post and core systems. Specimens were divided into 2 groups: - custom cast post and light transmitting post. Higher failure loads were obtained for the Light transmitting post compared to the Custom cast post which failed at much lower loads, the difference being statistically significant. The study concluded that mode of failure for Light transmitting post was favorable with all the samples fracturing at core level with minimum damage to tooth structure. For Custom cast post the failure mode was unfavorable as all samples showed root fracture and thus resulting in teeth that are non-restorable. Stress transfer was more with in the post and core unit for the Custom cast post compared to the Light transmitting post. Maximum stresses were observed in the cervical region for both the posts systems, but at different locations

***Dumbrigue et al (2006)***[53] investigated the fracture resistance of restored endodontically treated teeth when residual axial tooth structure was limited to one half the circumference of the crown preparation. The study showed that the predominant mode of failure was an oblique palatal to facial root fracture for the groups with remaining coronal tooth structure. A universal testing machine compressively loaded the tooth specimens from the palatal side at a crosshead speed of 0.5 cm/min at an angle of 135 degrees to the long axis of teeth until failure occurred. It was concluded that for restored endodontically treated teeth that do not have complete circumferential tooth structure between the core and preparation finish line, the location of the remaining coronal tooth structure may affect their fracture resistance.

***Markus Balkenhol et al (2007)***[54] examined the survival time of custom-fabricated, cast post and cores and evaluated the factors that influence the risk of failures over a period of time. They concluded that post and cores custom-fabricated using a standardized fabrication technique have a good long-term prognosis. The most common cause of failure is loss of retention. The durability of posts with low friction at the try-in stage could not be compensated by using glass ionomer cement as the luting material.

***Bolla, M.et al (2007)***[55] investigated the effect of different posts used for restoring endodontically treated teeth according to different elastic moduli and direction of the occlusal load by using finite element analysis. Stress distribution in the root depends on the elastic modulus and on the direction of the occlusal load. Elastic modulus of the core is less significant than elastic modulus of the post. The study concluded that the effect of the post on stress distribution varies according to the direction of the load: in a vertical load. The gold and carbon fiber posts generate lower stresses in the root than other metallic posts. When tested at an oblique load of 30 or 45 degrees, best results were obtained with a carbon-fiber post.

***Kerstin Bitter and Andrej M. Kielbassa (2007)***[56] reviewed on adhesive luting of fiber-reinforced composite posts (FRC) to provide evidence for the clinical procedure of restoring endodontically treated teeth using FRC posts. Compared to metal posts, FRC posts revealed reduced fracture resistance *in vitro*, along with a usually restorable failure mode. Bond strengths between FRC posts and resin cements could be enhanced by using various pre-treatment procedures; however, bonding to root canal dentin still seems to be challenging. Most clinical studies investigating survival rates of teeth restored with FRC posts revealed promising results, but *the* loss of coronal tooth structure had not been studied intensively.

***Accácio Lins do Valle (2007)***[57] compared the fracture resistance of endodontically treated teeth restored with prefabricated posts and composite resin cores with different post lengths. The results of the present study accepted the null hypothesis because they showed that the increase in post length in teeth restored with prefabricated posts and composite resin core did not significantly increase the fracture resistance of endodontically treated teeth. The prefabricated post-and-composite resin core groups showed crown composite resin core failure before occurrence of root fracture.

***Salameh Z (2008)***[58] investigated the influence of a fiber post on the fracture mechanism of zirconia crowns inserted over endodontically treated teeth with different extent of coronal damage. Fracture resistance and failure patterns of endodontically treated mandibular molars with and without glass fiber post in combination with a zirconia-ceramic crown was evaluated. The specimens were loaded to failure and were fractographically examined using a scanning electron microscope (SEM).The results revealed that specimens with fiber posts demonstrated significantly higher failure loads and favorable fracture pattern compared to the controls. The use of fiber post improved the support under zirconia crowns which resulted in higher fracture loads and favorable failure type compared to composite core build-up

***Kivanç BH* and *Görgül G*. (2008)**[59] investigated the fracture strength of three post systems cemented with a dual cure composite resin luting cement by using different adhesive systems. There was a significant difference in fracture resistance between the post systems and the interaction of adhesive resins and post systems. The study concluded that endodontically treated anterior teeth restored with glass fiber posts exhibited higher failure loads than teeth restored with zirconia and titanium posts. Self-etching adhesives are better alternatives to etch-and-rinse adhesive systems for luting post systems.

***Forberger N* and *Göhring TN* (2008)**[60] evaluated the marginal continuity and fracture behavior of high-strength all-ceramic crowns with different substructures in endodontically treated premolars. Marginal continuity of the crowns studied was better and more stress resistant, when posts and cores were included in the restoration of endodontically treated teeth with complete ceramic crowns. The placement of a post-and-core foundation did not influence the pattern of failure.

***Hassan Ahangari, Geramy and Valian (2008)***[61] evaluated stress distribution of endodontically treated maxillary central incisors restored with glass fiber posts, composite resin cores, and crowns with different ferrule designs. It was shown numerically that the presence of a ferrule reduced the stress findings in the cervical third of endodontically treated central incisors and there was no difference between stress findings in a tooth without a ferrule and the one with 0.5 mm of ferrule.

***John McLaren et al (2009)***[62] studied the effect of post type and length on the fracture resistance of endodontically treated teeth .Their study compared the fracture resistance of endodontically treated teeth restored with 3 different post systems, including 2 fiber reinforced posts and a stainless steel post .The results suggested that a stainless steel post may provide better support for the composite core than a fiber reinforced post when a 90 degree load is applied

***Kianoosh Torabi and Farnfiveaz Fatttahi (2009)***[63]compared the root fracture resistance of extracted teeth treated with different fiber reinforced with composite posts and treated with conventional post and core systems. The study showed that cast posts and cores had a higher failure threshold including teeth fracture; whereas fiber post failure was due to core fracture, with or without fractures in the coronal portion of the posts. Difference in FRC posts did not provide any significant difference in the load failure and the mode of fracture.

***Al-Omari and Zagibeh (2009)***[64] explored on the effect of fabrication technique, cement type and cementation procedure on retention of cast metal dowels. The results concluded that the fabrication technique did not affect the retention of the cast dowels except when luted with Zinc Phosphate cement without using a lentulospiral. The cementation procedure had a significant effect on the retention.

***Theodospoulou and Chochlidakis (2009)***[65] reviewed systematically to determine which dowel and core system was the most successful, when used in vivo to restore endodontically treated teeth. According to the studies carbon fiber in resin matrix dowels were significantly better than precious alloy cast dowels, glass fiber dowels were better than metal screw dowels and moderately better than quartz fiber dowels, carbon fiber dowels were worse than metal dowels and prefabricated metal dowels were slightly better than cast dowels.

***Alessandro Rogerio Giovani et al (2009)***[66] evaluated the in-vitro fracture resistance of roots with glass fiber and metal posts of different lengths. The study concluded that, in relation to the length, cast posts did not differ in terms of the compressive load required to fracture the load and that the glass fiber posts represented a viable alternative to the cast metal posts, increasing the fracture resistance of endodontically treated teeth.

***Jefferson Ricardo Pereira (2009)***[68] investigated the fracture strength of endodontically treated teeth restored with different posts and variable ferrule heights and all teeth were restored with full metal crowns. The investigation demonstrated that roots restored with individual cast posts exhibited higher fracture strength due to the ferrule preparation than those restored with prefabricated post and composite resin core.

***Toman M et al (2010)***[69] evaluated the effects of the different endodontic tooth colored posts and surface conditioning on the fracture resistance as well as the fracture modes of endodontically treated teeth. The study concluded that fracture resistance was significantly affected by the post material and surface conditioning.

The application of surface conditioning material to post surface decreased the fracture resistance of zirconia ceramic post with composite core and, glass fiber reinforced composite post with composite core.

***Dougals Terry and Edward Swift (2010)***[70] reviewed on the post and core from past to present. This review concentrated on the brief history, compared the current post systems and discussed the various techniques and failures that are encountered during the treatment and concluded that materials and techniques that are available should be evaluated for each clinical situation.

***Vaidya Vidya N & Chitnis Deepa P (2011)***[71] compared the fracture resistance of endodontically treated teeth with compromised intra radicular tooth structure using three different post systems. They investigated the validity of treatment of such teeth using cast post-core, intra-radicular resin reinforcement using composite resin followed by placement of prefabricated metal/fiber post (glass or carbon) and evaluate which post system is best suited for rehabilitation. There was no statistically significant difference between the 3 post systems, but it was observed that cast post and cores caused more apical and oblique fractures, rendering the teeth un-restorable. Teeth restored with intra-radicular resin reinforcement and placement of titanium or glass fiber post failed with root fractures limited to the coronal aspect along with dislodgement of post.

***Mangold J T & Kern M (2011)***[72] evaluated the influence of glass-fiber post placement on the fracture resistance of endodontically treated premolar with varying degrees of substance loss. The fracture resistance of endodontically treated premolar was dependent on the number of residual coronal dentin walls. Placement of a glass-fiber post had a significant influence on the fracture resistance when fewer than two cavity walls remained but no significant influence when two or three walls were present

# *Materials & Methods*

**MATERIALS**

- K – Files (DENTSPLY Maillefer, Ballaigues, Switzerland) for endodontic tooth preparation
- Gutta Percha points (DENTSPLY Maillefer, Ballaigues, Switzerland) for obturation of root canals
- Absorbent Paper points (DENTSPLY Maillefer, Ballaigues, Switzerland) for drying the root canal space
- Endodontic condensers–Spreaders & pluggers (DENTSPLY Maillefer, Ballaigues, Switzerland)
- Gates glidden drills (DENTSPLY Maillefer, Ballaigues, Switzerland) for shaping the coronal portion of the root canals
- Peso Reamers (DENTSPLY Maillefer, Ballaigues, Switzerland)
- Zinc oxide eugenol sealer (Dental Products of India, Mumbai, India )

- Lentulospiral (DENTSPLY Maillefer, Ballaigues, Switzerland) for carrying sealer into the root canal
- 5.25 % sodium hypochlorite solution ( d p, Dentpro ;Mohali, Punja , India)
- Normal Saline(NS, Baxter ; Alathur, Tamil Nadu, India)
- 15% EDTA solution for smear layer removal (Glyde, DENTSPLY Maillefer, Ballaigues, Switzerland)
- Cobalt Chromium Cast metal post (Wironium, Bego, Bremen, Germany)
- Stainless steel post (I-Post, Integrated Endodontics, Prime Dental, Mumbai, India) No.3
- Glass fiber reinforced post (Tenax Coltène/Whaledent Inc. OHIO, USA) 1.3mm diameter
- Carbon post (Reforpost;Angelus Germany ) 1.3mm diameter
- Zirconium Post( Cosmopost, Ivoclar Vivadent AG,Schaan/Leichtenstein, Switzerland) 1.4 mm
- Composite resin luting cement (Smart Cem2, DENTSPLY, Caulk, Milford, Detroit, USA)
- Dentin bonding agent (XP Bond DENTSPLY, De Trey, Caulk, Milford, Detroit, USA)

- Zinc Phosphate Cement (De Trey Zinc, DENTSPLY, DeTrey, Caulk, Milford, Detroit, USA),
- Composite Core Build Up material (Charisma, Hareaus Kulzer, Hanau, Germany) .
- 37 % Phosphoric acid for etching root dentin (DENTSPLY, DeTrey, Caulk, Milford, Detroit, USA)
- Addition silicone Impression material (Aquasil Ultra LV, De Trey, DENTSPLY, Caulk, Milford, Detroit, USA)
- Type IV Die stone (Kalabhai, Mumbai, India)
- Inlay Casting Wax (GC Corp, Tokyo, Japan)
- Cobalt Chromium Alloys (Wironium, Bego, Bremen, Germany)
- Investment Material (Wirovest, Bego, Germany)
- Clear acrylic – Heat cure resin polymer (Dental Products of India, Mumbai, India )
- Acrylic –Heat cure monomer (Dental Products of India, Mumbai, India )

**Equipments Used**

- Induction Casting machine (Fornax T, Bego, No:26300, Germany)
- Burn out furnace (Delta labs, Chennai, India)
- Sand Blaster (Dual Blaster, Delta labs, Chennai, India).
- Airotor hand piece ( NSK PANA AIR, JAPAN)

- Ultra sonic scaler (Satelac, P5 Booster; Merignac, France)
- Micromotor unit and airmotor hand piece for post space preparation (NSK PANA AIR, JAPAN)
- Crown preparation Burs ( Crown and bridge Preparation Kit, Shofu inc., Kyoto, Japan)
- Composite light curing unit ( DENTSPLY, Milford, Detroit, USA )
- Universal testing machine (Model 3345; Instron Corp, Canton, Mass, USA)

**METHODS**

**Selection of teeth and canal preparation**

Fifty human mandibular first premolars with roots of similar form were selected for the study, of which the specimens selected were from teeth after orthodontic extractions of individuals belonging to the age group of approximately twenty years, but not exceeding twenty five years. All the teeth selected had a single canal with straight roots measuring approximately 21mm. The teeth with caries; crack and restorations were not included in the study.

This present study evaluated the fracture resistance of endodontically treated teeth restored with conventional cast posts, stainless steel posts, glass fiber reinforced posts, carbon fiber posts and zirconia posts with composite core build up.

All external debris were removed from the tooth surface with an ultrasonic scaler (Satelac,$P_5$ Booster; Merignac, France) and the teeth were stored in normal saline solution; (NS, Baxter; Alathur, Tamil Nadu, India) when not under testing. The anatomic crowns of all teeth were sectioned just 2mm above the cemento-enamel junction with the use of a water cooled diamond wheel bur ( Crown and bridge Preparation Kit, Shofu inc., Kyoto, Japan) on an Air-turbine hand piece (NSK PANA AIR, Japan) at 300,000 rpm.

The exploration of the radicular canal was accomplished with No. 25 K-file (DENTSPLY Maillefer, Ballaigues, Switzerland).The selected specimens had a uniform working length of 17mm approximately. The preparation of entrance of the radicular canal was done with a flaring instrument; Gates Glidden drills of (DENTSPLY Maillefer, Ballaigues, Switzerland) sizes 2 and 3 were used to obtain straight line access in the middle and the coronal third of all specimens.

Routine endodontic treatment was accomplished with hand instruments using step back technique to a size of 40 for a master apical file. Silicone stoppers were placed around the K-file shaft to control the working length, thereby ensuring the accuracy of the internal canal dimensions. The canals were irrigated with 2.5% Sodium Hypochlorite solution (d p, Dentpro ; Mohali, Punjab, India) and Normal Saline (NS, Baxter; Alathur , Tamil Nadu, India) alternatively during the biomechanical preparation.

Once the canal preparation was over, canals were dried with absorbent paper points (DENTSPLY Maillefer, Ballaigues, Switzerland). Then the roots were obturated with Gutta percha points ((DENTSPLY Maillefer, Ballaigues, Switzerland) using Zinc oxide eugenol sealer (Dental Products of India, Mumbai, India ) .The master gutta percha point (size 40) was coated with sealer and seated in the canal to the predetermined working length. A finger spreader (DENTSPLY Maillefer, Ballaigues, Switzerland) was inserted into the canal to a level of approximately 1mm short of the full working length. Lateral condensation with non-standardized Gutta percha points (DENTSPLY, Maillefer, Ballaigues, Switzerland)) was performed until the entire canal was obturated. The excess Gutta percha was removed by using heated hand condensers. Vertical condensation was performed with the same instruments and the pulp chambers were sealed with Zinc oxide eugenol temporary restoration (Dental Products of India, Mumbai, India).

The most similar sizes available among the prefabricated post systems were used in the present study. The prepared roots were randomly divided into five groups with ten samples each (N=10 per group) according to the experimental procedures (post and core system) as follows:

Group 1— Cast metal post of Cobalt chromium obtained by Indirect procedure (Control Group)

Group 2—Glass fiber-reinforced resin posts ( Tenax Coltène/Whaledent Inc. OHIO, USA)

Group 3—Carbon fiber posts ( Reforpost, Angelus, Germany)

Group 4- Stainless steel posts ( I-Post, Integrated Endodontics, Prime Dental, Mumbai, India)

Group 5- Zirconium posts (Cosmopost, Ivoclar Vivadent AG, Schaan/Leichtenstein, Switzerland))

All teeth received 1.2 mm shoulder finish line preparations with the use of regular- and fine-grit parallel-sided, flat-end diamond burs (Crown and bridge Preparation Kit, Shofu inc., Kyoto, Japan) in a high-speed hand piece. The preparations had a wall convergence of approximately 6 degrees. Tooth reduction for crown preparation was performed to standard specifications. The crown margin was designed to follow the simulated contours of the free gingival tissue which was more apical compared to the proximal margins. The margins were 1 mm wide with a rounded shoulder configuration. A diamond rotary cutting instrument-Flat end tapered (Crown and bridge Preparation Kit, Shofu inc., Kyoto, Japan) with a 12-degree total occlusal convergence angle was used for the margin preparation of each tooth. Further a 2mm of incisal reduction and 1.5mmof facial reduction was done and then reduced to leave a 1-mm uniform ferrule. A shoulder of 1 mm in width and depth was then made at this level around the entire circumference of the tooth.

**Storage of prepared specimens**

Specimens were immersed in distilled water and maintained at $37^{0}{}_{C}$ for a period of 36 hours and 100 % humidity. The specimens were mounted in clear acrylic resin blocks (Acrylic cylinders with dimension of 3cm diameter and 2cm height, (Dental Products of India, Mumbai, India) with the long axis of each tooth parallel to the long axis of the block and the mid-facial extent of the cemento-enamel junction located 2mm coronal to the acrylic resin.

**Cast Metal Post Fabrication**

Custom made cobalt chromium cast post was casted by the indirect procedure in which an elastomeric impression material was used to make the impression of the root canal space with orthodontic wire reinforcement. Orthodontic wires were cut into appropriate length and were shaped to the letter “J”. Fit was verified in the canal so that it snuggly adapted to the canal and extended to a full depth of the post space .Now the wire was coated with tray adhesive (De-Trey Fix Adhesive, DENTSPLY, Caulk, Milford, Detroit, USA)and the canals were lubricated with die lubricant. Further the canals were filled with the elastomeric impression (Aquasil Ultra LV, De Trey, DENTSPLY, Caulk, Milford, Detroit, USA) material using a lentulospiral (DENTSPLY Maillefer, Ballaigues, Switzerland)) and the reinforcing orthodontic wire was placed in the canal space. A pick up impression was made of the whole assembly. A definitive cast was poured with Type IV Die stone (Kalabhai, Mumbai, India) and a wax pattern with inlay wax (GC Corp, Tokyo, Japan) was fabricated. The wax patterns were invested in a phosphate bonded investment material (Wirovest, Bego, Germany) using 1:1 special liquid-to-water ratio. Thirty minutes after the start of the mix, the investment was placed in a preheated burnout furnace (Delta labs, Chennai, India) at a temperature of $1100^0$C and left for forty five minutes. The patterns were casted in cobalt chromium alloys (Wironium, Bego, Bremen, Germany) with the aid of an Induction casting machine (Fornax T, Bego, No: 26300, Germany) .The final restoration was trimmed and finished. It was further air-particle abraded with 110 µm aluminum oxide powder in a sand blaster (Dual Blaster, Delta labs, Chennai, India).

**Cementation of the posts**

Canal spaces of all the specimens except for the Group 1 specimens were conditioned using EDTA (Ethylene diamine tetra acetic acid - Glyde, DENTSPLY

Maillefer, Ballaigues, Switzerland) for removing the smear layer. Canals were then flushed with distilled water and dried with absorbent paper points. The canal spaces were etched with 37% Orthophosphoric acid (DENTSPLY, DeTrey, Caulk, Milford, Detroit, USA) for twenty seconds, followed by copious irrigation with distilled water and were dried with absorbent points.

Cobalt chromium custom cast posts with cores were cemented using Zinc Phosphate cement (De Trey Zinc, DENTSPLY, DeTrey, Caulk, Milford, Detroit, USA), after drying the canals with absorbent paper points. The cement was delivered to the canal space with a lentulospiral (DENTSPLY, Maillefer; Baillagues, Switzerland) and castings were held in place under finger pressure until the cement has set. Excess cement was removed with a sharp hand instrument.

Each post in Group 2, 3 and 5 five was marked at 11mm from its apical end. A line was drawn around the post at this level and all the posts were sectioned horizontally with a water cooled diamond fissure bur.

The prefabricated posts of Group 2, 3 and 4 were coated with a resin cement (Smart Cem2, DENTSPL, Caulk, Milford, Detroit, USA) and inserted into the previously treated post space and the whole assembly was cured with visible light ( DENTSPLY, Caulk, Milford, Detroit, USA).

Zirconium posts (Group 5) were surface treated using 9.5% Hydrofluoric Acid (Bisco, Porcelain Etchant gel, Bisco Inc; Schamburg, Illinois, USA) followed by dentin bonding agent. These posts were cemented using the resin cement which was used for the Group 2,3 and 4 .

**Core Build Up**

A transparent heat cure (Dental Products of India, Mumbai, India) tooth shell of 5mm height was fabricated for the standardization of the core. The base of the shell was made to flush with the sectioned tooth surface. A small handle was attached to the superior surface for ease of placement and removal. Prepared tooth surfaces of specimens of Group 2, 3, 4 and 5 were treated with etchant gel (DENTSPLY, DeTrey, Caulk, Milford, Detroit, USA) for 20 seconds and the surfaces were thoroughly rinsed with water for 10 seconds. This was followed by application of a universal total-etch bonding agent (XP Bond DENTSPLY, De Trey , Caulk , Milford, Detroit, USA) and curing was done with visible light Composite light curing unit (DENTSPLY, Milford, Detroit, USA). The core was prepared to a height of 4mm by using transparent heat cure tooth shell for standardization, with composite core build up material (Charisma, Hareaus Kulzer, Hanau, Germany).

**Testing of the specimens**

Specimens were tested with a universal testing machine (Model 3345; Instron Corp, Canton, Mass, USA) set to deliver an increasing load until failure. The crosshead speed was 1 mm per minute, and the load was applied on the occlusal surface which was parallel to the long axis of the tooth. The specimens were tested in random order. The value of interest was the load at failure measured in Newton. The statistical analysis employed was 1-way analysis of variance (ANOVA) to detect the presence of group difference. Then a post hoc analysis was also conducted for pair wise comparisons between groups.

After testing under the Universal testing machine, the samples were analyzed visually for the type of fracture and it was found that:

The specimens of the

- Group1 (Cobalt chromium Cast post) did not fracture. But the post core material showed a shearing
- Group5 (Zirconium Posts) showed Vertical Root fracture in the cervical region
- Group 2, 3 and 4 (Glass fiber-reinforced resin posts, Carbon fiber posts and stainless steel posts) showed both core and post fracture.

# *Results*

In the present study, a total number of fifty samples were tested to determine the fracture resistance of five different endodontic post systems made of cobalt chromium, stainless steel, fiber reinforced composite, carbon fiber and zirconium ceramic. The specimens were divided into following five groups:

Group 1 : CMP

Group 2 : FRC

Group 3 : CFP

Group 4 : SS

Group 5 : ZRC

a) CMP denotes custom made cast metal post made

b) FRC denotes Fiber reinforced composite posts

c) CFP denotes carbon fiber posts

d) SS denotes stainless steel posts

e) ZRC denotes zirconia posts

Fracture resistance was determined using Universal testing machine by applying a static compression load and the maximum load at break was recorded, tabulated and are shown in the table 1 , 2, 3, 4 and 5.

## DESCRIPTION OF THE TABLES

**Table 1** shows the maximum load at which failure occurred for the samples of Group1 during the compression test.

The result is as follows:

***Group 1:*** The value of maximum load at failure ranges between 4.19 KN and 5.32 KN

**Table 2** shows the maximum load at which failure occurred for the samples of Group 2 during the compression test.

The result is as follows:

***Group 2:*** The value of maximum load at failure of Group 2 ranges between 1.83 KN and 2.42 KN

**Table 3**: shows the maximum load at which failure occurred for the samples of Group 3 during the compression test.

The result is as follows:

***Group 3:*** The value of maximum load at failure of Group 3 ranges between 1.41 KN and 2.19 KN

**Table 4** shows the maximum load at which failure occurred for the samples of Group 4 during the compression test.

The result is as follows:

***Group 4:*** The value of maximum load at failure of Group 3 ranges between 1.14 KN and 1.86 KN

**Table 5** shows the maximum load at which failure occurred for the samples of Group 4 during the compression test.

The result is as follows:

***Group 5:*** The value of maximum load at failure of Group 3 ranges between 1.96 KN and 2.60 KN

# STATISTICAL ANALYSIS OF THE RESULTS

The statistical analysis was performed using the software SPSS (statistical package for social sciences) version 16. The data was interpreted at a confidence interval of 95%.Analysis of variance test (ANOVA) was used to compare the fracture resistance of the intra-radicular systems used in the study. Post Hoc test followed by Scheffe Test was performed for multiple comparisons of the specimens.

The mean values obtained are shown in Tables 6, 7, 8, 9, 10 and 11.

The values are:

***Group I*** : 4.97±0.16

***Group II*** : 2.10±0.10

***Group III*** : 1.67±0.12

**Group IV**: 1.42±0.13

***Group V:*** 2.36±0.09

**Table 6** shows the mean value and the statistical significance of maximum load at failure of all the post systems in comparison with the cast metal posts.

One way ANOVA Test shows statistical significance of 0.05 at 95% confidence interval for Group II, III, IV and V in comparison with Group I.

**Table 7** shows the mean value and the statistical significance of maximum load at failure of the post systems in Group I, III, IV and V in comparison with the Fiber Reinforced composite posts (FRC).

One way ANOVA Test shows statistical significance of 0.05 at 95% confidence interval for Group I and IV in comparison with Group II.

**Table 8** shows the mean value and the statistical significance of maximum load at failure of the post systems in Group I, II, IV and V in comparison with the Carbon fiber posts (CFP).

One way ANOVA Test shows statistical significance of 0.05 at 95% confidence interval for Group I and V in comparison with Group III.

**Table 9** shows the mean value and the statistical significance of maximum load at failure of the post systems in Group I, II, III and V in comparison with the Stainless steel posts (SS).

One way ANOVA Test shows statistical significance of 0.05 at 95% confidence interval for Group I, II, and V in comparison with Group IV.

**Table 10** shows the mean value and the statistical significance of maximum load at failure of the post systems in Group I, II, III and IV in comparison with the zirconium posts (ZRC).

One way ANOVA Test shows statistical significance of 0.05 at 95% confidence interval for Group I, II, III and IV in comparison with Group V.

**Table 11** shows the comparison of compression test values between the groups.

One way ANOVA Test shows statistical significance of 0.05 at 95% confidence interval for Group I, II, III and IV in comparison with Group IV.

***Graph 1*** shows a statistical significance of 0.05 at 95% confidence interval with Groups II, III, IV and V

***Graph 2*** shows a statistical significance of 0.05 at 95% confidence interval with Groups I and IV

***Graph3*** shows a statistical significance of 0.05 at 95% confidence interval with Groups I and V

***Graph 4*** shows a statistical significance of 0.05 at 95% confidence interval with Group V

***Graph 5*** shows a statistical significance of 0.05 at 95% confidence interval with Groups I, III and

## Interpretation of Results

1. Cast metal posts showed the highest fracture resistance when compared with other groups.

2. Fiber reinforced composite posts showed fracture resistance value comparable with zirconia post. The fracture resistance value of FRC was higher than carbon fiber posts and stainless steel posts.

3. Carbon fiber posts showed lesser fracture resistance when compared to cast metal post and zirconia post. The value obtained was statistically insignificant on comparison with fiber reinforced composite and stainless steel post.

4. Stainless steel posts showed the least fracture resistance than all the post systems used in the study, but did not show any statistical difference in value between carbon posts.

5. Zirconia posts showed a higher value of fracture resistance which was comparable with fiber reinforced post, but was lesser than carbon fiber post and stainless steel post.

# Table-1

## Compression test for Cast Metal Posts (CMP) group

| Sample Number | Max. Load at Break (KN) |
|---|---|
| **CMP-1** | 5.31 |
| **CMP-2** | 4.19 |
| **CMP-3** | 5.03 |
| **CMP-4** | 4.88 |
| **CMP-5** | 5.25 |
| **CMP-6** | 5.16 |

# Table-2

## Compression test for Fiber Reinforce Composite Post (FRC)

## Group

| Sample Number | Max. Load at Break (KN) |
|---|---|
| **FRC-1** | 1.83 |
| **FRC-2** | 2.42 |
| **FRC-3** | 2.26 |
| **FRC-4** | 1.99 |
| **FRC-5** | 1.83 |
| **FRC-6** | 2.26 |

# Table-3

## Compression Test for Carbon Fiber Post (CFP) Group

| Sample Number | Max. Load at Break (KN) |
|---|---|
| **CFP-1** | 1.42 |
| **CFP-2** | 1.63 |
| **CFP-3** | 1.78 |
| **CFP-4** | 1.57 |
| **CFP-5** | 2.19 |
| **CFP-6** | 1.41 |

# Table-4

## Compression test for Stainless Steel (SS) group

| Sample Number | Max. Load at Break (KN) |
|---|---|
| **SS-1** | 1.50 |
| **SS-2** | 1.45 |
| **SS-3** | 1.14 |
| **SS-4** | 1.59 |
| **SS-5** | 1.86 |
| **SS-6** | 0.98 |

# Table-5

## Compression test for Zirconium Post (ZRC) group

| Sample Number | Max. Load at Break (KN) |
|---|---|
| **ZRC-1** | 2.44 |
| **ZRC-2** | 1.96 |
| **ZRC-3** | 2.34 |
| **ZRC-4** | 2.60 |
| **ZRC-5** | 2.47 |
| **ZRC-6** | 2.40 |

# Table-6

## Comparison of Compression test values of CMP with other groups

| GROUPS | Post type | Max. Load at Break (KN) (MEAN±SEM) |
|---|---|---|
| Group-I | Cobalt Chromium Post (CMP) | 4.97±0.16 |
| Group-II | Fiber Reinforced Composite Post (FRC) | 2.10±0.10* |
| Group-III | Carbon Fiber Post (CFP) | 1.67±0.12* |
| Group-IV | Stainless Steel Post (SS) | 1.42±0.13* |
| Group-V | Zirconium Post (ZRC) | 2.36±0.09* |

**[*P<0.05 significant compare CMP group with other groups]**

# Table-7
# Comparison of Compression test values of FRC with other groups

| GROUPS | Post type | Max. Load at Break (KN) (MEAN±SEM) |
|---|---|---|
| Group-II | Fiber Reinforced Composite Post (FRC) | 2.10±0.10 |
| Group-I | Cobalt Chromium Post (CMP) | 4.97±0.16* |
| Group-III | Carbon Fiber Post (CFP) | 1.67±0.12 |
| Group-IV | Stainless Steel Post (SS) | 1.42±0.13* |
| Group-V | Zirconium Post (ZRC) | 2.36±0.09 |

**[*P<0.05 significant compare FRC group with other groups]**

# Table-8

# Comparison of Compression test values of CFP with other groups

| GROUPS | Post type | Max. Load at Break (KN) (MEAN±SEM) |
|---|---|---|
| Group-III | Carbon Fiber Post (CFP) | 1.67±0.12 |
| Group-I | Cobalt Chromium Post (CMP) | 4.97±0.16* |
| Group-II | Fiber Reinforced Composite Post (FRC) | 2.10±0.10 |
| Group-IV | Stainless Steel Post (SS) | 1.42±0.13 |
| Group-V | Zirconium Post (ZRC) | 2.36±0.09* |

**[*P<0.05 significant compare CFP group with other groups]**

## Table-9

## Comparison of Compression test values of SS with other groups

| GROUPS | Post type | Max. Load at Break (KN) (MEAN±SEM) |
|---|---|---|
| Group-IV | Stainless Steel Post (SS) | 1.42±0.13 |
| Group-I | Cobalt Chromium Post (CMP) | 4.97±0.16* |
| Group-II | Fiber Reinforced Composite Post (FRC) | 2.10±0.10* |
| Group-III | Carbon Fiber Post (CFP) | 1.67±0.12 |
| Group-V | Zirconium Post (ZRC) | 2.36±0.09* |

**[*P<0.05 significant compare SS group with other groups]**

## Table-10

## Comparison of Compression test values of ZRC with other groups

| GROUPS | Post type | Max. Load at Break (KN) (MEAN±SEM) |
|---|---|---|
| Group-V | Zirconium Post (ZRC) | 2.36±0.09 |
| Group-I | Cobalt Chromium Post (CMP) | 4.97±0.16* |
| Group-II | Fiber Reinforced Composite Post (FRC) | 2.10±0.10 |
| Group-III | Carbon Fiber Post (CFP) | 1.67±0.12* |
| Group-IV | Stainless Steel Post (SS) | 1.42±0.13* |

**[*P<0.05 significant compare ZRC group with other groups]**

# Table-11

# Comparison of Compression test values

| GROUPS | Post type | Max. Load at Break (KN) (MEAN±SEM) |
|---|---|---|
| Group-I | Cobalt Chromium Post (CMP) | 4.97±0.16 |
| Group-II | Fiber Reinforced Composite Post (FRC) | 2.10±0.10 [1] |
| Group-III | Carbon Fiber Post (CFP) | 1.67±0.12 [1] |
| Group-IV | Stainless Steel Post (SS) | 1.42±0.13 [1,2] |
| Group-V | Zirconium Post (ZRC) | 2.36±0.09 [1,3,4] |

**[1= P<0.05 significant compare CMP group with other groups, 2= P<0.05 significant compare FRC group with other groups, 3= P<0.05 significant compare CFP group with other groups, 4=P<0.05 significant compare SS group with other groups]**

Fig 1 Prepared Specimens

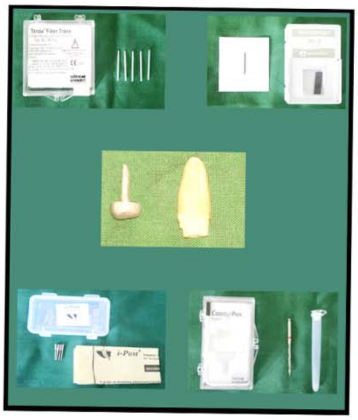


Fig 2 Different Post Systems


Fig 3 Armamentarium

Fig 4 Different posts on prepared teeth

Fig 5 Standardization of the core with acrylic shell

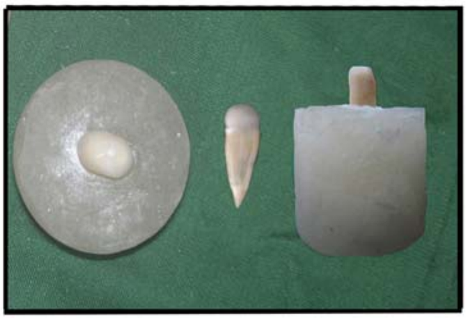


Fig 6 Specimen embedded in acrylic block

TESTING APPARATUS

Fig 7 INSTRON 3345

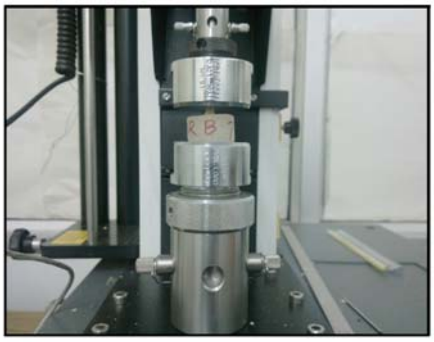
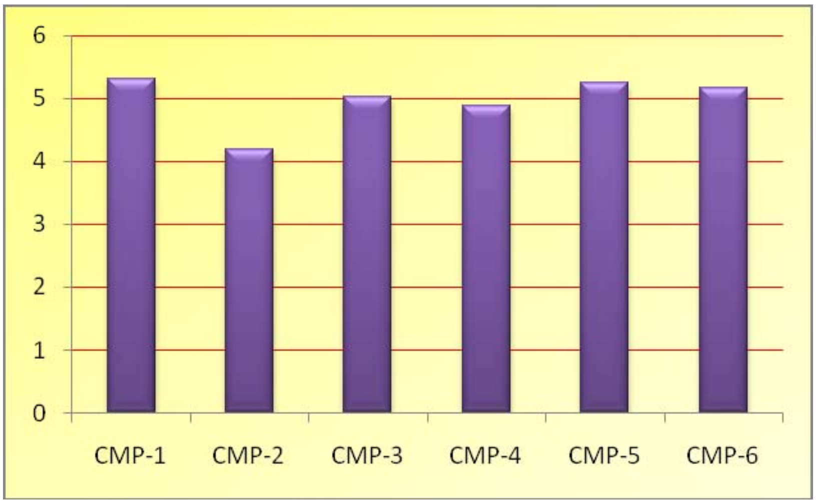


Fig 8 Specimen under compressive load

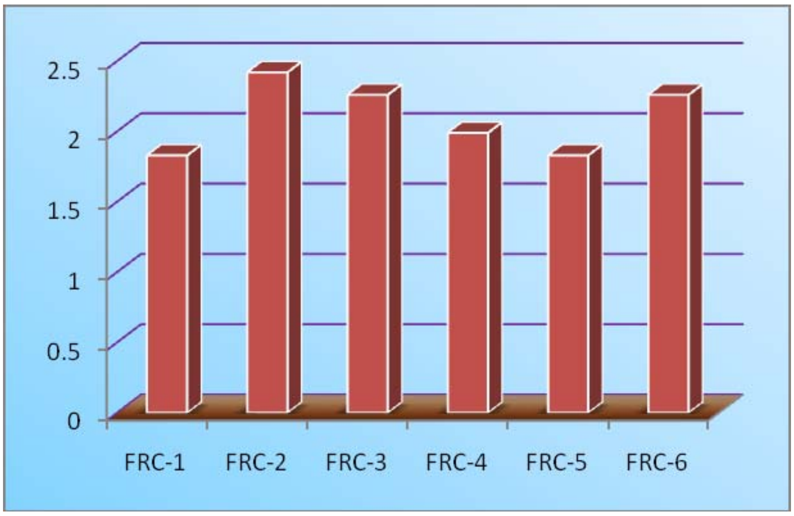
## Graph-1

## Compression test for CMP group



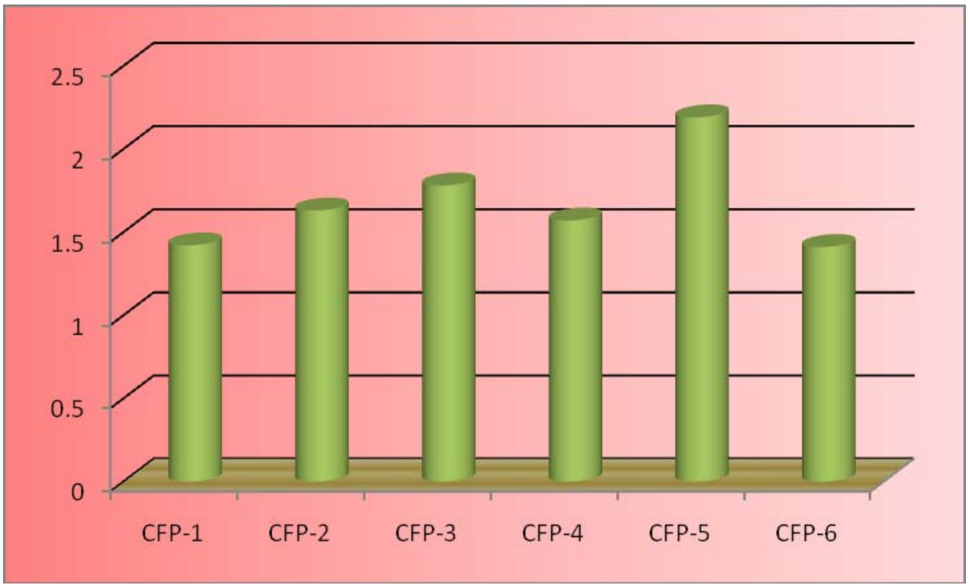

**Graph-2**

**Compression test for FRC group**



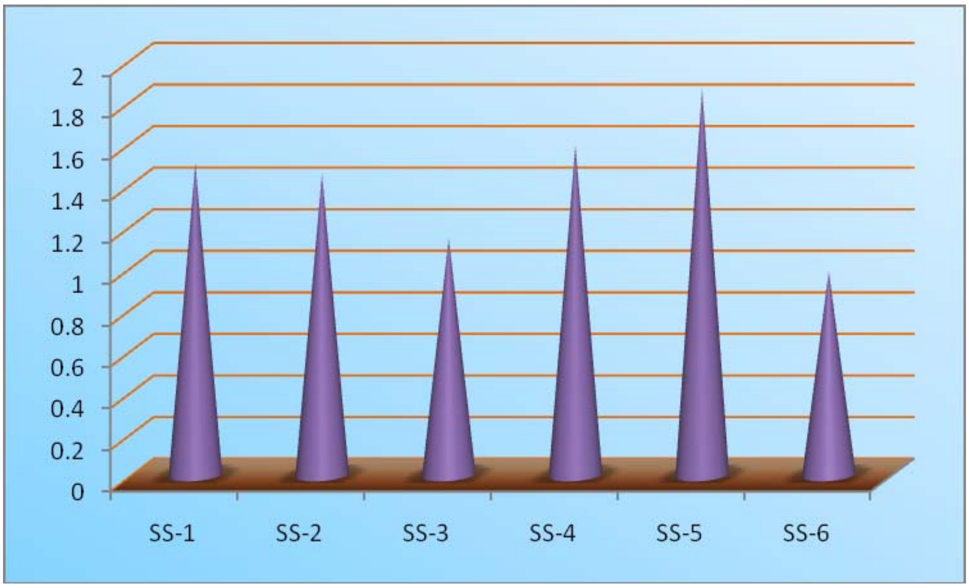

**Graph-3**

**Compression test for CFP group**



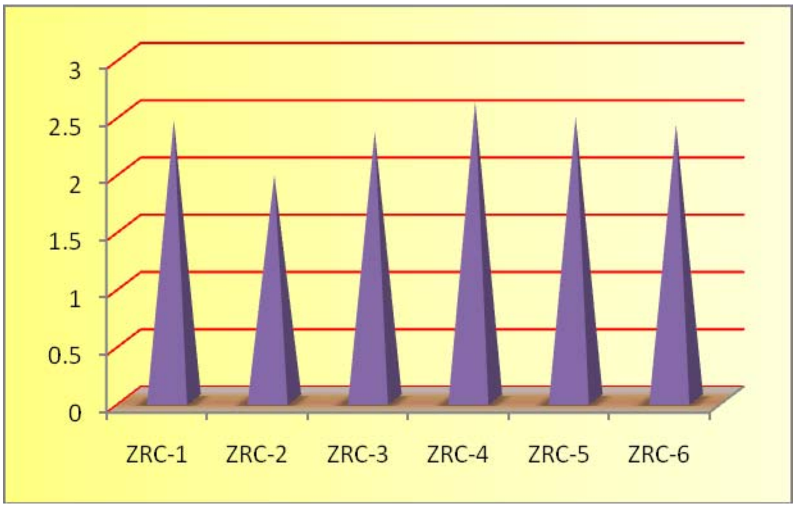

**Graph-4**

**Compression test for SS group**



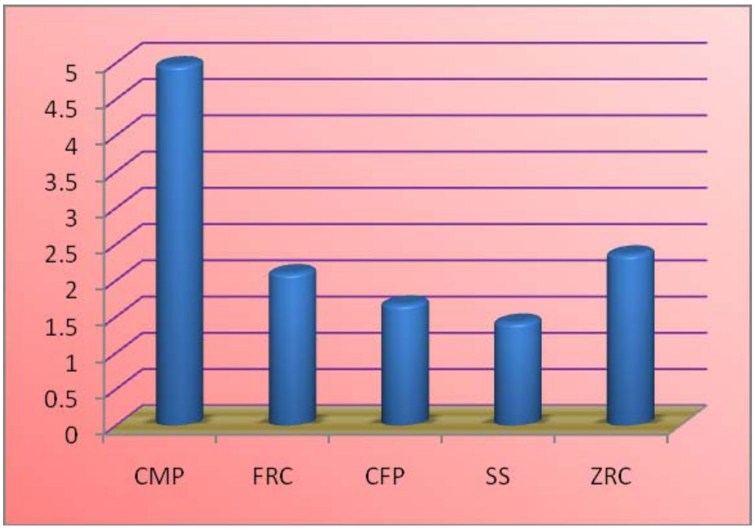

**Graph-5**

**Compression test for ZRC group**




**Graph-6**

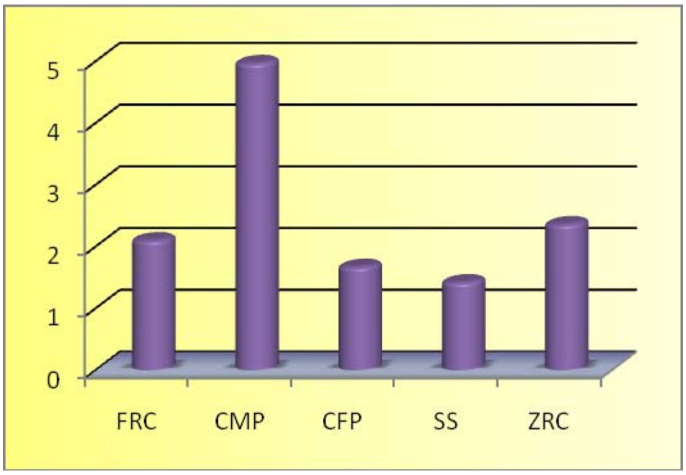
## Comparison of Compression test values of CMP with other groups




**[*P<0.05 significant compare CMP group with other groups]**

**Graph-7**

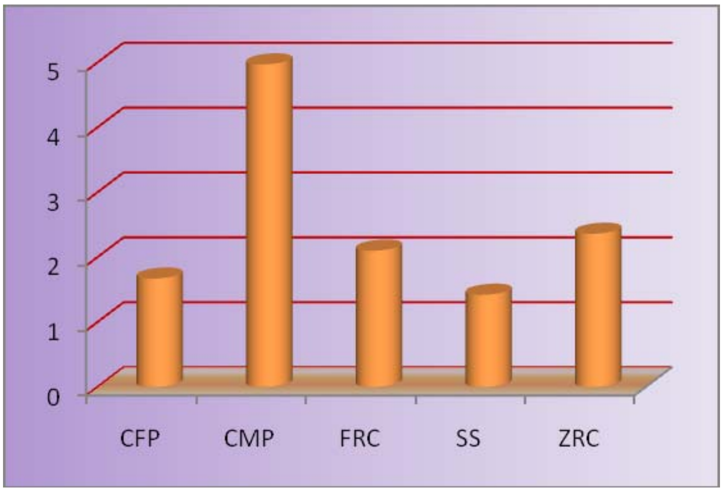
## Comparison of Compression test values of FRC with other groups




**[*P<0.05 significant compare FRC group with other groups]**

## Graph-8

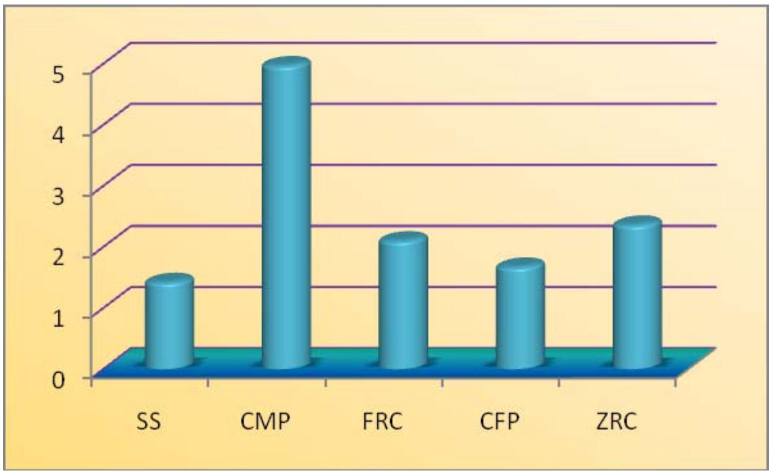
## Comparison of Compression test values of CFP with other groups




**[*P<0.05 significant compare CFP group with other groups]**

## Graph-9

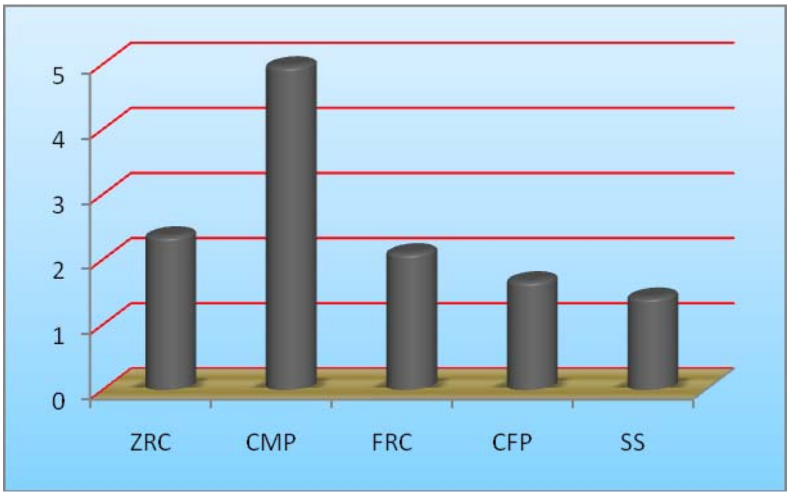
## Comparison of Compression test values of SS with other groups




**[*P<0.05 significant compare SS group with other groups]**

## Graph-10

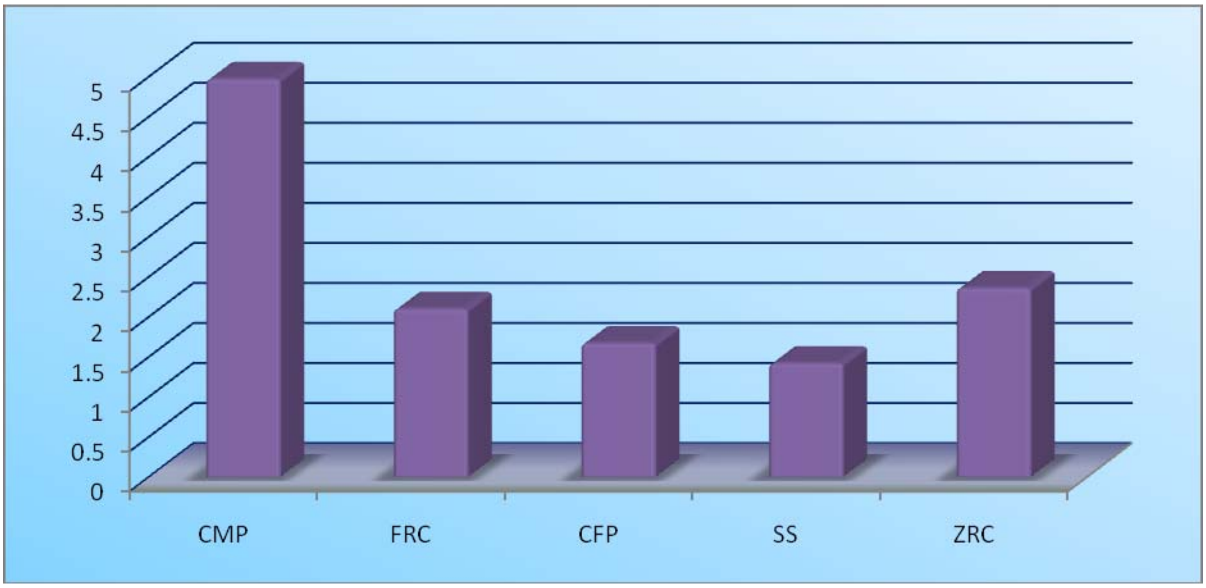
## Comparison of Compression test values of ZRC with other groups




**[*P<0.05 significant compare ZRC group with other groups]**

# Graph-11

## Comparison of Compression test values




**[1= P<0.05 significant compare CMP group with other groups, 2= P<0.05 significant compare FRC group with other groups, 3= P<0.05 significant compare CFP group with other groups, 4=P<0.05 significant compare SS group with other groups]**

# *Discussion*

Restoring endodontically treated teeth remains one of the most challenging problems facing the restorative dentist. The loss of dental tissue due to caries, trauma or large old restorations can be the reason for endodontic treatment of the tooth which reduces its mechanical solidity [43]. The compromised teeth have shown to exhibit a significantly shorter service life compared to normal vital teeth [42]. Devitalized teeth are brittle due to reduced amount of water, elasticity and increased fragility [23, 44]. This is mainly due to dessiccation or loss of moisture supplied by a vital tooth [50]. It is necessary to identify the best restorative methods for effectively reinforcing pulpless teeth with extensive loss of tooth structure for long term promising prognoses [46].

Endodontically treated tooth with decreased coronal tooth structure is an indication for intra radicular devices such as dowels or posts. These devices reinforce the root for providing foundation for the future extra-coronal restorations [8, 9]. Posts are often required to restore these teeth to provide retention and resistance for a core material and to provide a corono-radicular stabilization [65]. The selection of post system is important which has an influence in the survival of the tooth. The longevity of endodontically involved teeth has been greatly enhanced by continuing developments made in endodontic therapy and restorative procedures [27]. The post and core systems include the components of different degrees of rigidity. This enables the post system to resist forces without distortion, and stress is expected to transfer to the less rigid substrate [68, 69].

The intra-radicular devices available vary from conventional cast post and core system to commercially available prefabricated posts systems [27]. Fraga et al showed that roots restored with cast posts exhibited significantly higher internal stresses than the prefabricated posts [68]. Prefabricated posts are advantageous in situations where adequate tooth structure remains. They can be classified according to their structural composition as metal, ceramic or resin-reinforced with fibers. The advent of more advanced composite resin and ceramic materials has led to the development of wide variety of these non-metal endodontic posts [63].

In the present study, five different post systems were used for comparing the fracture resistance to evaluate the best choice of post and core system for clinical application. Fifty freshly extracted intact human mandibular premolars decoronated at a level of 2mm from the cemento-enamel junction were endodontically treated. Five groups of ten specimens were prepared (N=50). Specimens were immersed in distilled water and maintained at 37 $^{0}$ C for 72 hrs. Root canal post space preparation was initiated using gates glidden drill to remove 8mm of filling material. Each specimen was restored with posts of five different types. This included cobalt chromium cast metal post (group 1, control group), Glass Fiber reinforced post (group 2), Carbon post (group 3), Stainless steel post (group 4) and Zirconium post (group 5) of 1.3mm diameter.

The test specimens were cemented using Composite resin luting cement and control groups were cemented using zinc phosphate cement. The roots were further embedded in cylindrical acrylic resin blocks and a compressive load was applied on the posts along the long axis of the tooth. The specimens were loaded in a Universal Testing Machine (Model 3345 Instron Corp) and a compressive load was applied at 90 degrees to the occlusal surface [63], until fracture, at a cross head speed of 1mm/min. Since the natural teeth simulate the clinical conditions, their use for in vitro studies has been considered as acceptable [75]. A perpendicular angle of loading was used in the study as it has been shown to be the most traumatic force to a post and core system, and a likely manner in which many systems fail [63].

Selection of post and core system has largely been a discussion between the custom made cast metal post and the commercially available prefabricated post systems. Cast post and core has been regarded as the "Gold Standard" in post and core restoration due to its superior success rate, when coronal tooth structure is missing [19]. During the 1930s, the custom cast post-and-core was developed to replace the one piece-post crowns [71]. A metal dowel and core provides optimum strength and support for the veneer crown. From an esthetic point of view, however discoloration of the root and the gingiva caused by the metal color is a significant drawback [45]. As the cast metal post and core foundations have a long history of success use due to their superior properties [33, 52, 63] this was considered as the control specimen in the present in vitro study.

For fifteen years, endodontic posts made out of fiber reinforced composites have been described in the literature. The use of adhesively luted fiber reinforced composite posts introduced in 1997 [56, 58]. The increasing demand for more esthetic and biocompatible restorations led to the development of tooth-colored, translucent metal free posts and core systems. Prefabricated fiber reinforced composite posts were developed to satisfy esthetic needs. Over the last few years, fiber posts have become more popular and used because of their desirable physical properties and retrievability [16] in case of post failures. Fiber reinforced composite posts contain high percentage of continuous reinforcing fibers embedded in a polymer matrix [68]. The elastic moduli of fiber posts are closer to dentin than that of any metal post. Hence a conical quartz fiber material incorporated into the fiber reinforced composite post system was selected as one of the group for the study [39].

Carbon fiber posts were developed in France and introduced in USA. These translucent fiber posts can transmit light thereby permitting the light curing of the adhesive materials within the root canal. Its chemical nature is compatible with the BIS-GMA [17] commonly found in composite resins. The translucent fiber posts exhibit biocompatibility, high fatigue, tensile strength and modulus of elasticity comparable with that of dentin and other fiber posts [9, 10, 17, 38]. Hence this was used in the present study.

Stainless steel posts are prefabricated posts which are strong and are commonly used by the restorative dentists routinely. The stainless steel post selected for the present study had a design which compensated for the anatomical flare of the canal. The parallel and passive design of the stainless steel post prevents the fracture of the root under masticatory load. This characteristic feature of the post prevents the loosening of the post thus reducing the failure rate.

Zirconia post introduced by Meyeberg et al in 1995 [34], have a high flexural strength, increased biocompatibility, corrosion resistance and fracture toughness [22, 27, 34]. This material is difficult to cut intra-orally with a diamond and to retrieve for retreatment [71]. Due to the superior esthetic properties; zirconium posts are highly preferred for restoration of endodontically treated anterior teeth. This popularity of the material as per the literature reviews was the cause of including zirconium for the present study.

Using resins for luting in reinforced fiber post along with composite core makes it a monobloc. The latest generation of adhesive systems, produced by means of an etch technique causes the removal of smear layer and demineralization of the dentin, exposing a fine network of collagen fibrils. The infiltration of this network with resin dentin inter-diffusion zone (RDIZ) with resin tags and adhesive lateral branches thus creating a micro-mechanical retention of the resin to the demineralized substrate [17]. The monobloc effect created by the endodontic post and the adhesive resin along composite core creates superior strength to the system. The internal reinforcement with composites results in an increased fracture resistance of the weakened teeth with enlarged canals [30].

All the posts except cast metal posts were luted with resin cement. The literature presents numerous references commenting that the current resinous cements improve the capacity for the adhesion to the post, exhibit greater toughness and durability, less solubility and minimum microfiltration as well as esthetics in comparison with traditional luting cements.

Cast metal posts used in the present study were cemented with zinc phosphate cement due to its superior mechanical properties. This serves as a standard with which newer systems can be compared. Various literatures support this due to its high compressive strength (104MPa) and its resistance to elastic deformation even when employed as a luting agent for restorations that are subjected to high masticatory stress [8].

Ferrule design can also significantly improve the fracture resistance of endodontically treated teeth [64]. A ferrule is metal band or ring used to fit the root or the crown of a tooth Majority of the studies regarding the effectiveness of ferrule support the need of 1.5-2mm of ferrule height [24, 43]. The ferrule effect prevents fracture of the root and fracture of the post [30, 68]. It also prevents the dislodgement of the post and increase the fracture resistance of the endodontically treated teeth regardless of the dowel system used [24, 71]. Hence the ferrule effect was provided for all the samples.

Fracture resistance was determined using Universal testing machine by applying a static compression load and the maximum load at break was recorded. The value of maximum load at failure ranged between 4.19 KN and 5.32KN for the samples of Group1 during the compression test. The value of maximum load at failure of Group 2 was between 1.83 KN and 2.42, for Group 3 ranged between 1.41 KN and 2.19 KN, for Group 4 ranged between 1.14 KN and 1.86 KN and for Group 5 ranges between 1.96 KN and 2.60 KN.

Posts with Young’s modulus similar to dentin, that is about 18 GPa [69] are desirable because of a more homogenous stress distribution reducing the risk of fracture. Static force ranges from 100-1000 Newtons while dynamic or functional force ranges from 3.5 to 350 Newtons [33]. In the present study, all the post systems failed above the masticatory load and hence all these materials can be considered for restoration of endodontically treated teeth, based on the appropriate clinical situations [46].

In the present study, cast metal posts made of cobalt chromium alloys showed highest fracture resistance which was highly significant when compared with other groups. This is in agreement with the studies conducted by Frank Tane Dilmener et al [50] and Sonthi Sirimai et al [12]. The cast posts have a high modulus of elasticity when compared with the other post systems [52]. This might be the reason for the shearing of the specimen in this group when a compressive load was applied. The higher compressive strength of zinc phosphate cement and the ferrule effect also might have led to the high fracture resistance of the cast metal posts. But the cast metal post has the potential to transfer and concentrate the applied stresses to the compromised tooth structure which can lead to the catastrophic fracture at high load [52].

In the present study, glass fiber reinforced composite posts showed a higher value of fracture resistance when compared with carbon fiber posts and stainless steel posts. The fiber reinforced composite posts and the zirconium oxide posts did not show a statistical difference, but when compared to the cast metal posts, all the other samples showed lower resistance. Fiber reinforced composite posts presented with post fracture whereas the zirconium oxide posts presented with vertical root fracture event though there was no significant difference between the values. This is in agreement with the studies conducted by Novais et al and Akkayan et al. Zirconia posts have a modulus of elasticity of 820 Mpa which is much higher than dentin. This may account for the fracture under compressive load of all teeth restored with zirconia posts.

The present study is not in agreement with Dilmener et al [50] whom in his literature suggested the use of zirconia posts to be more advantageous than cast metal posts as it preserves the recipient roots.

In the present study fiber reinforced composite posts showed post fracture. This is in agreement with studies conducted by Akkayan et al [23], Naovais et al [68] and Frank Seefeld [58].

The matrix of fiber reinforced composite post system generally consists of PMMA chains of high molecular weight. Fiber reinforced composite posts showed a modulus of elasticity about 20 MPa which is comparable with that of dentin [46]. Another reason for the high fracture resistance can be due to the reinforcing effect of fibers.

Pre-stressed fibers are soaked with resins and released after curing. This procedure causes compression of glass fibers which are able to absorb the stresses while the post is exposed to flexural forces .Pre-treatment of fiber surfaces by sandblasting or silanization techniques also improves the strength of the fiber- matrix interface [58]. The post system used in the study has filler -matrix value of 14612

[58]. An explanation might be that, increase in fiber surface area can increase the resistance to fracture if the interfacial bonding between the fibers and the resin matrix works perfectly [40, 58, 69].

In the present study, carbon fiber posts showed lowest fracture resistance when compared with the specimens other than stainless steel. But the values were statistically insignificant with that of the stainless steel post. This is in agreement with the study of M Ferrari et al [17] and Novais et al [68].

The modulus of elasticity of carbon posts is closer to that of dentin. According to Novais et al the carbon fiber posts showed more intimate contact between the carbon fibers and the resin matrix. But the lowest value obtained may be due to the post composition and orientation of fibers. In relation to fiber orientation, fibers diverging from the posts in longitudinal axis results in stress transmission to the matrix. Posts with parallel fibers are able to withstand loads better than loads with obliquely oriented fibers [69]. So this orientation of fibers might have attributed to the lowest fracture resistance of carbon fiber posts.

In this study, stainless steel posts were found to have least fracture resistance. Low modulus of elasticity allows greater bending under load. But when strain exceeds the yield point, the material is irreversibly deformed even after the load has been removed. Stainless steel post has higher modulus of elasticity [46]. But the ferrule effect given on the endodontically treated teeth might have helped in withstanding catastrophic root fracture and thus resulted in breakage of the post.

Thus it can be suggested that a post with same modulus of elasticity of root dentin should be used to distribute the applied forces evenly along the length of the post, thereby preventing the root fracture.

Although this in vitro method of test to detect the fracture resistance is to correlate the clinical relevance, the limitation exists in the interpretation of the results from a clinical perspective [4, 68, 69]. As only a mono-static load is applied, this study does not fully replicate oral condition where dynamic forces come into play.

Periodontal ligament was also not simulated in this experiment [43, 68]. The teeth were held in place with rigid acrylic resin which is more akin to an ankylosed tooth [43].

Further research into the effect of cyclic loading on similar specimens with simulated periodontal ligament can provide more clinical relevance. Additionally, microscopic and radiographic examination of the post –tooth interfaces to determine the initial failure can also be done.

# ***Summary & Conclusion***

## Summary

The present study was done to evaluate the fracture resistance of five different post systems which were commonly used for restoring endodontically treated teeth with major loss of coronal tooth structure. For the present study, fifty freshly extracted mandibular first premolars were endodontically treated and prepared for receiving intra-radicular devices. Compression test was done to assess the fracture resistance of the materials used. The results were recorded, tabulated and analyzed. Statistical analysis was performed using appropriate tests and the data were interpreted.

## Conclusion

Within the limitations of the study, the following conclusions were drawn.

1. Teeth restored with Cast Metal posts and cores exhibited the highest fracture resistance.

2. The teeth restored with cast posts and prefabricated posts showed significant difference in fracture resistance.

3. Teeth with Glass Fiber Reinforced Composite post exhibited fracture resistance closer to carbon and zirconia posts.

4. Carbon fiber posts exhibited fracture resistance which was higher than Stainless Steel posts.

5. Stainless Steel post had a significantly lower fracture resistance when compared to all the other post systems used in the present study.

6. Shearing of the cast post was observed at high loads which is not desirable due to its detrimental effect on the surrounding tissues.

7. The teeth restored with Zirconia posts showed catastrophic vertical root fracture, hence should be avoided in case of patients with para-functional habits.

8. Fiber Reinforced Composite post and Carbon fiber post showed fracture of post and not the root. Hence the above mentioned posts can be used for patients with higher masticatiory load thus preserving the remaining tooth structure.

From the data obtained from the present study it can be concluded that the Fiber Reinforced Composite posts and Carbon fiber posts can be suggested as best options for reinforcing endodontically treated teeth with loss of coronal tooth structure. These post systems with favorable properties and retrievability can be considered as ideal material of choice among various dowel-core systems. Along with the best choice of material, the monobloc effect and the ferrule effect should also be created for a clinically successful post and core system.

# *Bibliography*


1. Guzy GE, Nicholls JI In vitro comparison of intact endodontically treated teeth with and without endo-post reinforcement. J Prosthet Dent. 1979 Jul; 42 (1):39-44.

2. Chan, R., and Bryant, R. Post-Core Foundations for Endodontically Treated Posterior Teeth. J Prosthet Dent Vol 48, 401-06, 1982.

3. John A. Sorensen & Michael J. Engelman, Effect of post adaptation on fracture resistance of endodontically treated teeth Journal of Prosthet Dent.1990 Oct; 64 (4) 419-424.

4. Brett I Cohen, Allan S. Deutsch and Barry Lee Musikant, Cyclic fatigue testing of six endodontic post systems. Journal of Porsthodontics, Vol 2, NO.1 (March), 1993:28-32.

5. Marie Charlotte and Paul GT, Mechanical longevity estimation model for post and core restorations. Dental Materials 11 (1995) 252-257.

6. Charles J Goodacre and Kenneth J. Spolnik. The prosthodontic management of endodontically treated teeth: a literature review. Part III. Tooth preparation considerations Journal of Porsthodontics, Vol 4, Issue 2 (1995), 122-128.
7. Duret, B., Duret, F., and Reynaud, M. Long-Life Physical Property Preservation and Postendodontic Rehabilitation with the Composipost. Compendium. 17: S50-S56, 1996.
8. Daniel B Mendonza, W. Stephan Eakle and Ernest A. Kahl, Root reinforcement with a resin bonded preformed post. J Prosthet Dent 1997; 78:10-15.
9. Giovanni E. Sidoli, Paul King and Derik Setchell, An in vitro evaluation of a carbon fiber based post and core systems. J Prosthet Dent 1997;78:5-9.
10. Arturo Martinez-Insua, Luis Da Silva, Benito Rilo and Urbano Santana, Comparison of fracture resistance of pulpless teeth restored with a cast post or carbon fiber post with a composite core. J Prosthet Dent 1998; 80:527-532
11. Lawrence W Stockton, Factors affecting retention of post systems: A literature review. J Prosthet Dent 1998; 81:380-385.
12. Sirimai S, Riis DN, Morgano SM. An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet Dent 1999;81:262-269.
13. Bruce Glazer, Restoration of Endodontically Treated Teeth with Carbon Fiber Posts — A Prospective Study. Can Dent Assoc 2000; 66:613-8.
14. Rosentritt, Fürer C, Behr M, Lang R, Handel G., Comparison of in vitro fracture strength of metallic and tooth-colored posts and cores. 2000 Jul; 27 (7):595-601.

15. Scotti, R. and Malferrari, S., Prosthetic aspects of endodontically treated tooth restoration. 5th International Symposium. 27-33, 2001.
16. Cormier C., Burns, D., Moon, P. , In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. J Prosthodont. 2001 Mar; 10 (1):26-36.
17. Marco Ferrari, Alessandro Vichi and Simone Grandini, Efficacy of different adhesive techniques on bonding to root canal walls: an SEM investigation. Dental Materials, Volume 17, (2001) 422-429.
18. Hong so, Hong Soyang, Lisa A Lang, Antony Molina and David Felton, The effects of dowel designs and load direction on dowel and core restorations. J Prosthet Dent 2001; 85:558-567.
19. Frank Butz, Aine M. Lennon, Guido Heydecke and Jorg R. Strub, Fracture strength and survival rate of endodontically treated maxillary incisors with approximal cavities after restoration with different post and core systems: an in-vitro study, The International journal of prosthodontics (2001) Volume: 14, Issue: 1, 58-64.
20. Mark S Hagge, Ralan Wong and James.S.Lindemuth, Effect of dowel space preparation and composite cement thickness on retention of a prefabricated dowel. J Prosthodont 2002; 11:168-175.
21. Mark S Hagge, Ralan Wong and James. S. Lindemuth, Retention strengths of Five luting cements on prefabricated dowels after root canal obturation with Zinc oxide eugenol sealer: 1.Dowel space preparation/Cementation at one week after obturation. J Prosthodont 2002; 11:19-24.

22. Seung Mi Jeong, Klaus Ludwig and Matthias Kern, Evaluation of the fracture resistance of all-ceramic zirconia posts by 3 different methods International Journal of Prosthodontics, 2002; 15:154-158.
23. Begum Akkayan and Turgut Gulmuz, Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent 2002; 87: 431-7.
24. Stankiewicz NR, Wilson PR. The ferrule effect: A literature review. Int Endod J 2002;35 (7): 575-581.
25. J W Robbins, Restoration of endodontically treated tooth. Dental Clinics of North America, 46 (2002) 367-384.
26. Heydecke and Peters M C, The restoration of endodontically treated single rooted teeth with cast or direct post and core – A systemic Review. J Prosthet Dent 2002; 87:380-6.
27. Aquaviva Fernandes, Sharath Shetty and Ivy Coutinho, Factors determining post selection: A literature review. J Prosthet Dent 2003:90:556-62.
28. Albuquerque R C, Polleto LT, Fontana RH, Cimini CA., Stress analysis of an upper central incisor restored with different posts. J Oral Rehabil. 2003 Sep; 30 (9):936-43.
29. Oliviera, L.C.A., Candido, M.S.M., Duarte, S., Oliviera, S.A.G., Comparative study of stress distribution in upper incisors; biometric behavior of post systems. AADR, 2003.
30. Marcela P Newman, Peter Yaman, Joseph Dennison, Mary Rafter and Edward Billy, Fracture resistance of endodontically treated teeth restored with composite posts. J Prosthet Dent 2003; 89:360-7.

31. Borcic, J, Finite element study of the glass fiber endodontic posts. J Dent Res. Vol 83 (Spec. Iss. A) 2004.
32. Gaivile Pileicikiene, Algimantas Surna, The human masticatory system from a biomechanical perspective: A Review. Stomatologija, Baltic Dental and Maxillofacial Journal, 6:81-84, 2004.
33. Richard S Schwartz and Robbins, Post placement and restoration of endodontically treated teeth: A literature review. Journal of Endodontics Vol. 30, No.5, May 2004.
34. Alireza Sahafi, Anne Peutzfeldt, ErikAsmussen and Klaus Gotfredsen, Retention and failure morphology of prefabricated posts Int J Porsthodont2004;17:307-312.
35. Cedomir Oblak, Peter Jevnikar, Tomaz Kosmac, Nenad Funduk and Ljuo Marion, Fracture resistance and reliability of new zirconia posts. J Prosthet Dent 2004; 91:342-348.
36. Vytaute Peciuliene and Jurate Rimkuviene Vertical Root Fractures in Endodontically Treated Teeth: A Clinical Survey. Stomatologija, Baltic Dental and Maxillofacial Journal, 6:77-80, 2004.
37. Steven M Morgano and Carlos Sabrosa Restoration of endodontically treated teeth. Dental Clinics of North America April 2004 Vol. 48, Issue 2, 397-416.
38. Erik Asmussen, Anne Peutzfeldt and Alireza Sahafi, Finite element analysis of stresses in endodontically treated dowel restored teeth.J Prosthet Dent 2005; 94:632-9.
39. Graziela Avila Galhano, Luiz Felipe Valandro, Renaata Marques de Melo, Roberto Scotti and Marco Antonio Bottino, Evaluation of the flexural strength of carbon fiber, quartz fiber and glass fiber based posts. Journal of Endodontics, Vol 31, No 3, March 2005.

40. Simone Grandini, Cecilia Goracci, Franklin R. Tay, Romano Garndini and Marco Ferrari, Clinical evaluation of the use of Fiber posts and direct resin restorations for Endodontically Treated Teeth. Int J Porsthodont. 2005; 18:399-404.
41. Alessandro Lanza, Raffaella Aversa, Sandro Rengo, Daide Apicella and Antonio Apicella, 3D FEA of cemented steel, glass and carbon posts in maxillary incisor. Dental Materials (2005) 21, 709-715.
42. Philip Tan Stephen Aquilino, David Gratton, Clark M Stanford , Sweechiantan, William Johnson and Deborah Dawson, In vitro fracture resistance of endodontically treated central incisors with varying ferrule heights and configurations. J Prosthet Dent 2005; 93:331-6-50.
43. Dermendgieva, k. Markova, Stefanova, Manolova Manggukova And Mantchorova Application of intra-radicular posts in the restoration of endodontically treated teeth in the clinical practice -A pilot study. Journal of IMAB, Annual proceeding; (2005) Book 2
44. Emine Yalcin, Murat Sechreli and Scenay Cany, Fracture Resistances of Cast Metal and Ceramic Dowel and Core Restorations: A Pilot Study. Journal of Prosthodontics. June 2005, Vol 14, Issue 2, 84-90
45. Yoshihiro Goto, Jack Nicholls, Kieth Philips and Thomas Junge, Fatigue resistance of endodontically treated teeth restored with three dowel and core systems. J Prosthet Dent 2005; 93:45-50.
46. Mikako Hayashi, Yutaka Thakahashi, Satoshi, Imazato and Shigyuki Ebisu Fracture resisitance of pulpless teeth restored with post-core and crowns. Dent Mater. (2006) 22, 477-485.

47. Ioli Ioanna Artopoulou, Kathy L Kefe and John M Power, Effect of core diameter and surface treatment on the retention of rein composite core to prefabricated endodontic posts. J Prosthodont 2006; 15: 172-179.

48. Nakamura T, Ohyama T, Waki T, Kinuta S, Wakabayashi K, Mutobe Y, Takano N, Yatani H. Stress analysis of endodontically treated anterior teeth restored with different types of post materials. Dent Mater J. 2006 Mar; 25(1):145-50.

49. Okada, D., Miura, H., Suzuki, C., Komada, W., Yamamoto, M., Masouka, D., Shin, C. Stress Distribution in Root Restored with Different Post Systems. J Dent Res 85, (Special Issue B), 2006.

50. Faruk Taner Dilmener, Cumhur Sipahi and Mehmet Dalkiz, Resistance of three new esthetic post and core systems to compressive loading. J Prosthet Dent 2006; 95:130-136.

51. Anil Kishen, Mechanisms and risk factors for fracture predilection in of endodontically treated anterior teeth, Endodontic Topics, 2006, 13, 57-83.

52. Panna Narang, B.V. Sreenivasa Murthy and Sylvia Mathew, Evaluation of two post and core systems using fracture strength test and finite element analysis. Journal of Conservative Dentistry, 2006 Vol : 9 Issue : 3 , 99-103.

53. Ng C C Dumbrigue H B, Al-Bayat MI, Griggs J A, Wakefield C W, Influence of remaining coronal tooth structure location on the fracture resistance of restored endodontically treated anterior teeth. Journal of Prosthetic Dentistry. 2006 April 95, (4)2:90-296.

54. Markus Balkenhol, Bernd Wostmann, ChristianRein and Paul Ferger, Survival time of cast post and cores: A 10-year retrospective study. Journal of dentistry 35 ( 2007) 50-58.
55. Bolla, M., Laplanche, O., Leforestier, E., Muller-Bolla, M., Influence of Elastic Modulus of Posts on Stress Distribution. J Dent Res. Vol 86 (Spec. Iss. A) 2007.
56. Kerstin Bitter, Post-endodontic restorations with adhesively luted fiber-reinforced composite post systems: a review. Am J Dent 2007; 20:353-360.
57. Accácio Lins do Valle, Jefferson Ricardo Pereira, Fábio Kenji Shiratori, Luiz Fernando Pegoraro and Gerson Bonfante, Comparison of the fracture resistance of endodontically treated teeth restored with prefabricated posts and composite resin cores with different post lengths. J. Appl. Oral Sci. vol.15 no.1 Bauru Jan./Feb. 2007.
58. Frank Seefeld, Hans-Jurgen Wenz, Klas Ludwig and Matthias Kern, Resistance to fracture and structural characteristics of different fiber reinforced post systems. Dental Material (2007), 23 (3); 267-271.
59. Salmeh, Ounsi HF, Aboushelib MN, Sadig W, Ferrari M. Fracture resistance and failure patterns of endodontically treated mandibular molars with and without glass fiber post in combination with Zirconia ceramic crown. Journal of Dentistry, 36; (2008), 513-519.
60. Kivanc B H and Gorgul, Fracture resistance of teeth restored with different post systems using new-generation adhesives. J Contemp Dent Pract. 2008 Nov 1; 9 (7):33-40.

61. Forberger N and Gohring Influence of the type of post and core on in vitro marginal continuity, fracture resistance, and fracture mode of lithia disilicate-based all-ceramic crowns. J Prosthet Dent. 2008;100 (4):264-73.
62. Hassan Ahangari and Valian, Ferrule Designs and Stress Distribution in Endodontically Treated Upper Central Incisors: 3D Finite Element Analysis. Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2008; Vol: 5, No.3).
63. John D McLaren, Charles I McLaren, Peter Yaman, Mohammed S Bin-Shuwaish, Joseph D. Dennison and Neville J. McDonald, The effect of post type and length on the fracture resistance of Endodontically Treated teeth. J Prosthet Dent 2009; 101:174-182.
64. Kianoosh Torabi & Farnaz Fattahi, Fracture resistance of Endodontically Treated teeth restored by different FRC posts: an In vitro study. Indian Journal of Dental research, 20 (3), 2009, 282-287.
65. Wael M Al-Omari and Zagibeh, The retention of cast metal dowels fabricated by direct and indirect techniques. Journal of Prosthodontics 19 (2009) 58-63.
66. Joanna N Theodosopoulou, Konstantinos And Chochlidakis, A systematic review of Dowel and core materials and systems. Journal of Prosthodontics 18 (2009) 464-472.
67. Alessandro Rogerio Giovani, In vitro fracture resistance of glass fiber and cats metal posts with different lengths. J Prosthet Dent 2009; 101:183-188.
68. Veridiana R Novais, Paulo S Quagiliatto, Alvaro Della Bona, Lourenco Correr-Sobrinho and Carlos J Soares, Flexural, flexural strength and stiffness of fiber reinforced posts. Indian J Dent Res, 20 (3) 2009.

69. Jeffreson Ricardo, Accacio Lins do Valle, Fabio Kenji Shiratori, Janaina Salomon Ghizoni and Murilo Periera de Mello, Effect of intra-radicular post and crown Ferrule on the Fracture strength of Endodontically Treated Teeth. Braz Dent J (2009)20 (4): 297-302.

70. Toman M, Toksavul S, Sarikanat M, Nergiz I, Schmage P Fracture resistance of endodontically treated teeth: effect of tooth colored post material and surface conditioning. Eur J Prosthodont Restor Dent. 2010 Mar; 18(1):23-30.

71. Douglas A Terry and Edward J swift, Post and cores: Past to present. International dentistry SA; 2010: Vol.12, No. 2.

72. Vaidya, Vidya N & Chitnis Deepa P, A comparative evaluation of the fracture resistance of endodontically treated teeth with compromised intra radicular tooth structure using three different post systems. People's Journal of Scientific Research Year: 2011 Vol: 4 Issue: 1 ; 6-11.

73. Mangold JT, Kern M. Influence of glass-fiber posts on the fracture resistance and failure pattern of endodontically treated premolars with varying substance loss: An in vitro study. J Prosthet Dent. 2011 Jun;105(6):387-93.

74. Jasmina Bijelic, Sufyan Garoushi, Pekka K Vallittu and Lippo V J Lassila, Fracture load of tooth restored with fiber reinforced post and experimental short fiber composite. The Open Dentistry Journal, 2011, 5, 58-65.